Handbook of European Freshwater Fishes

Maurice Kottelat and Jörg Freyhof

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Suggested citation format
Kottelat, M. and J. Freyhof. 2007. Handbook of European freshwater fishes. Kottelat, Cornol, Switzerland and Freyhof, Berlin, Germany.

ISBN 978-2-8399-0298-4

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Printed by Imprimerie du Démocrate SA, Delémont, Switzerland

Published by the authors

Available from:
Publications Kottelat
Case postale 57
CH-2952 Cornol
Switzerland
publications_kottelat@bluewin.ch

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Foreword

On current assessments and projections, there may be anything between 25,000 and 40,000 species of fish in the world. This high global diversity of fishes, including at least 14,000 species in freshwaters, remains the least well known among the vertebrates. As many as three hundred new species of fish are scientifically described and named every year, even in geographical areas where knowledge has been assembled over centuries. This pattern of discovery is certainly the case for European freshwaters, where the nature and identity of the fishes has long been considered to be 'well known' and also 'impoverished'; but where, remarkably, not less than 56 species new to science have been determined since the year 2000 (10 % of the entire list of native species). In the present impressive publication, Drs Maurice Kottelat and Jörg Freyhof recognize the existence of 546 native species in European freshwaters. This contrasts strongly with the 25 species originally listed in Guillaume Rondelet's *Universae aquatilium historiae* (1555), one of the earliest accounts of European freshwater fishes.

The *Catalogue of the fishes in the British Museum* (1859-1870) by Albert Günther constitutes the last scientific benchmark publication in which all of the European freshwater fishes known at that time can be found under a single cover. Since then, standard works have characteristically listed only between about 160 and 270 species - depending in part on taxonomic concepts and geographical definitions. Now, after more than a century of what might be regarded in some respects as 'ichthyological stasis', Kottelat and Freyhof clearly demonstrate that the diversity of European freshwater fishes is far greater than commonly believed. There are, in fact, about twice as many fishes in European rivers, streams, lakes, swamps and ponds than often hitherto recognised. This case is fully substantiated by the authors through fieldwork, a re-examination of museum material, the utilisation of vital new voucher specimens, the development of innovative techniques and analytical processes and a wide-ranging expert consultation.

Kottelat and Freyhof have thoroughly reviewed the published data and drawn on their own original researches. In a close and fruitful collaboration extending over nine years, these authors have travelled widely in 24 European countries to gather the fish material needed for comparisons of taxa across ecological, geographical and political boundaries, including in countries where it is difficult to gain access and scientific permits. Forty-seven undetermined species (most of them new to science) were discovered by Kottelat and Freyhof during these "expeditions" to every corner of Europe, extending west to Portugal and east to the Caspian Sea basin. They have surveyed everything from rapids to acid swamps and brackish lagoons; from deep, glacial Alpine lakes to shallow, warm coastal Mediterranean ponds and the sluggishly flowing brooks of the Greek islands. The great majority of species are figured in colour and many that had not been illustrated before have been photographed alive.

This substantial and well documented European fish diversity is often still ignored in the wider scientific and popular literature. Traditional perspectives and, in some cases, national or local interests can result in a tendency to accept the historical *status quo* and discount or ignore this diversity. In such cases the real 'victims' are the fishes. That is to say, by ignoring this diversity we negate the existence of species which, in many instances, are rare and threatened (and in some cases are likely close to extinction) and which urgently need conservation measures to be put in place. Accordingly, the conservation status of all species has been evaluated by the authors, following the IUCN Red List Categories and Criteria (details of which will soon be available on-line on www.iucnredlist.org), and this results in the alarming observation that 200 European freshwater fish species (38 %) are threatened.

The threats leading to declines and extinction are multiple and often act in synergy: drought, excessive water abstraction, habitat loss or degradation (pollution, eutrophication, damming, channelisation and other waterworks) are among the main ones. With the often negative aquatic

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effects of global climate change and ever more extensive agricultural impacts, the threats to ecosystems and individual species or populations will certainly increase. For fish diversity to persist and prosper, there will need to be a major effort in terms of the ecological rehabilitation of water bodies; and the current European Union Water Framework Directive intends that by the end of 2015 all surface waters will be able to fulfil scientific criteria for a "good ecological status". Precise definitions for these criteria are, nonetheless, still under debate.

Introductions of invasive alien species of fish and other waterlife and the resulting negative perturbations in ecosystems are an increasing concern. The present work, however, points to a less obvious and insidious aspect of introductions. A number of apparently widely distributed species of European fish (such as minnows, gudgeons and trouts) have been transported across drainage divides, often stocked for recreational purposes or used as bait. But we now have evidence that some supposedly common and widely distributed taxa are, in fact, distinct species that have been introduced (sometimes in massive numbers) into the range of other similar and closely allied species, resulting in hybridization, 'genetic pollution' and local extirpations. Sadly and paradoxically, some of these no-doubt well-intentioned transfers have been made by agencies in charge of the conservation of local fish communities in order to increase or strengthen endangered populations.

Biological and environmental issues aside, it is vital that European freshwater fishes are conserved for their huge economic value both in terms of wild capture fisheries and aquaculture. Populations of extremely valuable commercial species such as the European eel (*Anguilla anguilla*) and sturgeon (*Acipenser sturio*) have declined drastically over the last 50 years from anthropogenic factors; and these and many other species now need to be managed sustainably.

Last, the Freshwater Fish Specialist Group of Species Survival Commision (SSC) of The World Conservation Union (IUCN) and Wetlands International is delighted to fully endorse this publication and the North of England Zoological Society has been pleased to lend encouragement and financial assistance. In offering congratulations to the authors, one may wonder why European ichthyology has waited so long for such an authoritative treatment.

Professor Gordon McGregor Reid,
Global Chair of the
IUCN-SSC/WI Freshwater Fish Specialist Group

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Preface

"One assumes that when [experimental biologists] state that they used 5 ml ethanol, they were not using 6 ml of methanol; and yet, if the experimental animal is wrongly identified, what are the grounds for such an assumption?"

Kevan (1973: 1212)

This project started on a sunny Sunday in July 1961 when a younger first author, armed with a small bucket, finally caught his first fish (a minnow) in the River Doubs and proudly brought it back home and released it into an inflatable swimming pool. The ichthyophily slowly evolved into ichthyology to reach the final stages of the ichthyomania now observable.

The second author followed a similar ontogeny. Grown up in an aquarium shop, resources were the only limit to his attraction for the diversity of fishes. With time, this interest and the enthusiasm for field biology combined with the study of the fish in its environment and of the mechanisms leading to the diversification of fishes. He is another victim of ichthyomania, showing the most obvious symptom, a total incapacity to cross a bridge without looking down into the water ...

The meeting of these trajectories and the respective lamentations about the state of taxonomy of European freshwater fishes created the desire to attempt to remedy this situation.

Our motivation to write this book originated from the obvious discrepancies between the information in various old and not-so-old books on European freshwater fishes and what we saw when we started to have a closer look at these fishes in the field. We quickly decided that we were definitely not interested in rehashing compilations of compilations of the published data but instead, we wanted to find as much actual information as possible on the diversity, habitat, distribution, biology and conservation of all the species and to see them in the wild with our own eyes. It is hard to quantify the efforts that went towards collecting all the data and pictures presented in this book. Altogether we visited 24 European countries (out of 40) during 40 field trips and spent eight years examining both our material and that in museums. We have seen a large number of the species alive and examined preserved samples of most. This allowed us to check most of the identification characters ourselves.

At the very beginning, we were aware of 'signals' indicating that the diversity of European freshwater fishes was underestimated, but we did not foresee the extent of this. The books often used as standard references for diversity mentioned about 170 species in the early 1990s in Europe excluding the former USSR. In 1997, a critical review of the literature pertinent to systematic analysis and an update of the nomenclature found 358 species for the same area, and gave the shocking image of an abandoned field unaware of modern concepts and methods used elsewhere in the ichthyological world. 2350 years of European ichthyology since Aritotle and 450 years of 'modern' ichthyology since Rondelet, Gessner, Belon, Salviani and Artedi resulted in this?

The first victim of this tragic neglect has been the fish diversity. Ignoring this diversity has already resulted in the extinction (because of transplantation, hybridisation and introgression of other species) of a few species whose identity had been negated in the scientific literature but now turn out to have been distinct, plus those we never knew existed. A majority of the European freshwater fishes are under threat because the size of their ranges has been grossly overestimated leading to the conclusion that the species were safe. In fact, most ranges are smaller than previously thought, so that populations could easily be impacted by a single threat. A single pollution episode or a single introduction of rainbow trout or any other exotic predator could wipe out an endemic fish from

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the single spring it is known to inhabit.

The number of species we recognized increased steadily during our work and several important groups still await a critical taxonomic revision. A number of species described by earlier authors, and ignored by later workers, had to be re-validated. Altogether at least 47 species new to science were discovered during the work on this book, of which five still await a formal name. There is no doubt that exploration of the European fish fauna is still far from complete. The northern European coregonids remain the less well-known group of European freshwater fishes and we still cannot (even roughly) estimate their taxonomic diversity.

We recognize here 546 native and 33 introduced (of which 28 are established) species in European freshwaters west of the Urals, including a number of unnamed ones. We would have liked to provide formal names for all the species, but this would probably have delayed completion of the book for years. We feel that it is more useful to present as many species as possible now, even if some of them are unnamed. This will hopefully attract attention to these species and the need for their conservation and study.

The aim of this book is to describe the diversity of European freshwater fishes. While the origin and the organization of biodiversity is a fascinating topic, describing diversity is a somewhat boring activity, unless one has a dedicated interest for a given group of fishes. As an example, we recognize 34 species of barbels (*Barbus* and *Luciobarbus*) in Europe. All look very similar; at a first look, they may just appear as the same species with a few small differences from river to river. They are, however, all distinct species. This book is aimed as a basic reference for identifying species also as conservation units and we hope that it will help to protect the European biodiversity in all its aspects.

Looking further at these 'boring barbels', one realizes that at some localities two, three or even four species may occur together. In theses cases, the different species have very different ecologies and then we reach the unresolved questions of the organization of biodiversity. In two species of barbels, hybridisation might have been involved in speciation. Hybridisation is just recently being assumed to be one of the causes of the origin of species [cynically, anthropogenic hybridisation is nowaday also a cause of extinction of species]. Some species of barbels have large and some have very restricted distribution ranges. The 'boring barbels' become 'interesting barbels' and nice indicators for the reconstruction of the evolution of European drainages and their faunas. We hope we managed to attract attention to the most interesting aspects of our enigmatic fish fauna.

This project ended because there was a need to publish the results and the present level seemed almost acceptable. Of course, for many species, more material should have been examined to improve the keys and diagnoses. That would have automatically resulted in the discovery of more species or more problems, thus further delays, further new discoveries, etc. Of course, for many species, more hidden, national literature should have been analyzed to provide better and more exact data on biology. But all this would have endlessly postponed publication. We feel that the point of diminishing return has been reached and decided that it is time to publish, before more species, alas, go extinct...

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Acknowledgements

This book would not have been possible without the help and contributions of numerous persons. First of all, we owe special thanks to Nina Bogutskaya, Jörg Bohlen and Primož Zupančič for providing the backbone of several species accounts. Nina Bogutskaya also extensively commented on several sections of the text and shared her knowledge of Russian fishes and literature. Kelvin Lim for the line drawings; and Jane Whitten and Rohan Pethiyagoda for helping us to improve the language of the text—we are responsible for all remaining mistakes.

A major condition for the preparation of this book was to base it on fresh material and field observations. We are pleased to acknowledge the colleagues and friends who facilitated our work and assisted in the field (in alphabetical order): Ashgar Abdoli (Tehran, Iran), Krasen Andonovski (Skopje, Macedonia), Roberta Barbieri (Athens, Greece), Dominique Beaudou (Montpellier, France), Patrick Berrebi (Montpellier, France), Nina Bogutskaya (St. Petersburg, Russia), Jörg Bohlen (Libechov, Czechia), Philippe Derenne (Toulouse, France), Oleg Diripasko (Berdyansk, Ukraine), Panos S. Economidis (Thessaloniki, Greece), Willi Ernst (Utting, Germany), Jean-Michel Foissy (Montpellier, France), Andreas Geiger (Überlingen, Germany), Pierre-Yves Genet (Poitiers, France), Simo Georgiev (Skopje, Macedonia), Mikael Himberg (Abo, Finland), Juraj Holčík (Bratislava, Slovakia), Jan Kotuz (Wrocklav, Poland), Josef Lechner (Weyregg, Austria), Stanislav Lusk (Brno, Czechia), Yuryi Movchan (Kiev, Ukraine), Alexander Naseka (St. Petersburg, Russia), Christophe Noël (St-Ursanne, Switzerland), Arne Nolte (Köln, Germany), Henri Persat (Lyon, France), Bruno Polli (Bellinzona, Switzerland), Meta Povž (Ljubljana, Slovenia), Vladimir Poznjak (Elista, Russia), Miroslaw Przybylski (Lodz, Poland), Petr Ráb (Libechov, Czechia), Dmitri Sendek (St. Petersburg, Russia), Uli Schliewen (München, Germany), Maria Stoumboudi (Athens, Greece), Suzana Šumer (Ljubljana, Slovenia), Philippe Théate (Montpellier, France), Josef Wanzenböck (Mondsee, Austria), Grzegorz Zieba (Lodz, Poland), Primož Zupančič (Ljubljana, Slovenia); and numerous fishermen, anglers, and fisheries officials.

We thank the numerous colleagues who provided fish specimens, information or photographs (in alphabetical order): Colin Adams (Glasgow, U. K.), Vítor Almada (Lisboa, Portugal), Roberta Barbieri (Athens, Greece), Pier Giorgio Bianco (Napoli, Italy), Alain Crivelli (Arles, France), Bo Delling (Stockholm, Sweden), Giovanni Delmastro (Carmagnola, Italy), Ignacio Doadrio (Madrid, Spain), Panos S. Economidis (Thessaloniki, Greece), Benigno Elvira (Madrid, Spain), Simo Georgiev (Skopje, Macedonia), Jörn Gessner (Berlin, Germany), Menachem Goren (Tel Aviv, Israel), Juraj Holčík (Bratislava, Slovakia), Anders Klemetsen (Tromsø, Norway), Sven Kullander (Stockholm, Sweden), Jan Kusznierz (Wroclaw, Poland), Ioannis Leonardo (Ioannina, Greece), Peter Maitland (Haddington, U. K.), Drago Marić (Podgorica, Montenegro), Milorad Mrakovčić (Zagreb, Croatia), Rudolf Müller (Kastanienbaum, Switzerland), Jorgen Nielsen (København, Denmark), Henri Persat (Lyon, France), Bruno Polli (Bellinzona, Switzerland), Meta Povž (Ljubljana, Slovenia), Joana Robalo (Lisboa, Portugal), Maria Stoumboudi (Athens, Greece), Davut Turan (Rize, Turkey), Zoran Spirkovski (Ohrid, Macedonia), Stefano Valdesalici (Viano, Italy).

Our work also required the examination of material accumulated by the generations of ichthyologists who worked before. These samples, in part, still exists in natural history museums and we thank the following colleagues and institutions for allowing access to the material under their care (in alphabetical order of cities): Sonia Fisch-Muller, Claude Weber (Muséum d'Histoire Naturelle, Genève, Switzerland), Müfit Özuluğ (Istanbul University, Turkey), Alan Hudson, Rudolf Müller, Pascal Vonlanten (EAWAG, Kastanienbaum, Switzerland), Judite Alves (Museum Bocage, Lisboa, Portugal), James Maclaine (Natural History Museum, London, U. K.), Angel Garvia (Museo Nacional de Ciencias Naturales, Madrid, Spain), Guy Duhamel, Patrice Pruvost

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(Muséum National d'Histoire Naturelle, Paris, France), Todor Ivanovski (Macedonian National Museum of Natural History, Skopje, Macedonia), Sven Kullander (Swedish Museum of Natural History, Stockholm), Panos S. Economidis (formerly Department of Zoology, Aristotle University, Thessaloniki, Greece), Nina Bogutskaya (Zoological Institute, Russian Academy of Sciences, St. Petersburg, Russia).

This book greatly benefits from the numerous photographs generously made available by friends and colleagues. We are happy to thank the following for providing illustrations used in this book: the Countryside Council for Wales (Bangor; U. K.), the Centre for Ecology and Hydrology (CEH, Bangor, U. K.), the Freshwater Biological Association (FBA, Ambleside, U. K.), and the Society for Protection of Lake Prespa (Agios Germanos, Greece); Asghar Abdoli (Tehran, Iran), Harald Ahnelt (Wien, Austria), Nobuhiko Akiyama (Shizuoka, Japan), Gavin Alexander (Glasgow, U. K.), Mahmoud Bacha (Béjaïa, Algeria), Roberta Barbieri (Athens, Greece), Rüdiger Bless (Bonn, Germany), Nina Bogutskaya (St. Petersburg, Russia), Jörg Bohlen (Libechov, Czechia), Magret Bunzel-Drüke (Bad Sassendorf, Germany), Laura Corrigan (Durham, U. K.), Bo Delling (Stockholm, Sweden), Andrew Ferguson (Belfast, U. K.), Werner Fiedler (Leipzig, Germany), Georg Fridriksson (Stockholm, Sweden), Jörn Gessner (Berlin, Germany), Andreas Hartl (Dorfen, Germany), Mikael Himberg (Abo, Finland), Zeb Hogan (Reno, U.S.A.), Kimberly L. Howland (Winnipeg, Canada), Volker Huckstorf (Berlin, Germany), Alan Hudson (Kastanienbaum, Switzerland), Lukas Kalous (Libechov, Czechia), Anders Klemetsen (Tromsø, Norway), Alexander Konovalov (St. Petersburg, Russia), Egbert Korte (Stockstadt, Germany), Marcelo Kovačić (Rijeka, Croatia), Peter Maitland (Haddington, U. K.), Luiz R. Malabara (Porto Alegre, Brazil), Hilmar J. Malmquist (Kópavogur, Iceland), Drago Marić (Podgorica, Montenegro), Ian McCarthy (Anglesey, U. K.), Rudolf Müller (Kastanienbaum, Switzerland), Theodor Nalbant (Bucuresti, Romania), Alexander Naseka (St. Petersburg, Russia), David Neely (St. Louis, U.S.A.), Svein Tore Nilsen (Talvik, Norway), Arne Nolte (Québec, Canada), Müfit Özuluğ (Istanbul, Turkey), Tiit Paaver, (Thallin, Estonia), Henri Persat (Lyon, France), Vasily I. Ponomarev (Syktyvkar, Russia), Meta Povž (Ljubljana, Slovenia), Yuri S. Reschetnikov (Moskow, Russia), Michel Roggo (Fribourg, Switzerland), Zoltan Sallai (Túrkeve, Hungary), Ulrich Schliewen (München, Germany), Johannes Schöffmann (St. Veit, Austria), Alena Sediva (Libechov, Czechia), Ole Seehausen (Kastanienbaum, Switzerland), Ivar Steinmann (Bonn, Germany), Maria Stoumboudi (Athens, Greece),Tan Heok Hui (Singapore), Sako Tuniev (Sochi, Russia), Pascal Vonlanthen (Kastanienbaum, Switzerland), Ruud Wildekamp (Gemert, Netherlands), Koji Yamazaki (Tokyo, Japan), Gerald Zauner (Engelhartszell, Austria), Zhou Hang (Guangzhou, China), Randy J. Zemlak (Prince George, Canada) and Primož Zupančič (Ljubljana, Slovenia).

We thank Petter Oscarson (Lund, Sweden) for permission to reproduce illustrations published in Oikos.

IUCN (through Caroline Pollock) granted permission to reproduce the definitions and table of the Red List Categories and Criteria. Kevin Smith and Will Darwall, Freshwater Biodiversity Unit, IUCN Species Programme, coordinated the evaluation of the Red List status and the validation process and assisted in obtaining funding for printing. Kevin Smith entered the data into the IUCN Red List database and generated the maps.

The North of England Zoological Society (Chester Zoo) provided financial support to the costs of printing. We are pleased to thank Gordon Reid, Director General, for his support and for agreeing to write the Foreword. The IUCN Species Programme also provided some financial support for producing the species distribution maps and helping to draft the conservation chapter.

It is impossible to estimate how many nice and helpful people we met and how many unpublished information from numerous and anonymous local experts, fishermen, anglers are included in this book. To all we have a great debt of gratitude.

All this work would not have been possible without Antoinette Kottelat-Kloetzli and Susanne Klähr who supported and helped at most stages of the work, endured our frequent absences, endless fish stories, and the hectic last weeks of the preparation of this book.

Sources

While this book is the authors' work, for which we assume responsibility, we relied for a number of species accounts, in part or largely, upon data provided or translated by Nina G. Bogutskaya, Jörg Bohlen and Primož Zupančič. These data have been edited, completed, modified or adapted to fit the style and format of the book. In order to give them proper credit for their data, we list here the accounts for which these data have been used:

Nina Bogutskaya: *Alosa kessleri*, *Parabramis pekinensis*, *Luciobarbus brachycephalus*, *L. capito*, *Barbus ciscaucasicus*, *B. kubanicus*, *B. tauricus*, *B. waleckii*, *Alburnus hohenackeri*, *A. chalcoides*, *Aspius aspius*, *Chondrostoma kuban-*

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icum, *C. oxyrhynchum*, *C. variabile*, *Delminichthys* spp., *Rhynchocypris percnurus*, *Hypophthalmichthys* spp., *Leuciscus danilewskii*, *Petroleuciscus borysthenicus*, *Phoxinellus* spp., *Rutilus caspicus*, *R. frisii*, *Scardinius dergle*, *S. plotizza*, *Squalius aphipsi*, *Telestes croaticus*, *T. fontinalis*, *T. metohiensis*, *Ctenopharyngodon idella*, *Mylopharyngodon piceus*, *Oxynoemacheilus merga*, *Hypomesus olidus*, *Osmerus* spp., *Coregonus autumnalis*, *C. baerii*, *C. luttoka*, *C. maraenoides*, *C. maxillaris*, *C. muksun*, *C. nasus*, *C. peled*, *C. pidschian*, *C. sardinella*, *Stenodus* spp., *Hucho taimen*, *Oncorhynchus gorbuscha*, *Salmo ciscaucasicus*, *S. ezenami*, *Salvelinus alpinus*, *S. lepechini*, *Thymallus arcticus*, *Oryzias sinensis*, *Gymnocephalus acerina*, *Percarina demidoffii*, *P. maeotica*, *Perccottus glenii*, *Benthophilus* spp., *Caspiosoma caspium*, *Knipowitschia bergi*.

Jörg Bohlen: *Cobitis* spp., *Sabanejewia balcanica*, *S. caucasica*, *S. larvata*, *S. romanica*.

Primoz Zupančič: *Aulopyge huegelii*, *Chondrostoma knerii*, *C. phoxinus*, *C. scodrense*, *Delminichthys* spp., *Phoxinellus* spp., *Squalius illyricus*, *S. microlepis*, *S. svallize*, *S. tenellus*, *S. zrmanjae*, *Telestes croaticus*, *T. fontinalis*, *T. metohiensis*, *T. polylepis*, *T. turskyi*, *T. ukliva*.

Kevin Smith, IUCN Species Programme, generated and edited the maps from the data entered in the IUCN Red List database and wrote the backbone of the Conservation status chapter.

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Introduction

Coverage. All species of freshwater fishes recorded from European inland waters are included. Diadromous and sporadic species are also included. Accidental species are mentioned and sometimes included in keys but are not given full treatment.

The boundaries of Europe as understood here are shown on the map. Iceland, Spitzberg and New Zemblia are included. The eastern boundary is made by the Baidaratsa Bay and the Ural Range divide as far south as Orsk. From Orsk southward, the border is defined by the divide between the Ural River and the Or (a tributary entering the Ural at Orsk) and the Sagiz and Emba (two Caspian Sea tributaries). In the Caucasus, the border is made by the Greater Caucasus range; it (approximately) starts to the west at the Black Sea near the Russian city of Novorossiisk, then runs along the Caucasus divide until Baku (Azerbaidjan) on the Caspian Sea. The upper-most reaches of the Terek in Georgia are also included, as is Turkey, north of the Bosphorus. In the Aegean Sea, the boundary follows the political border between Greece and Turkey. Crete and Malta are included, Cyprus is not included. Spanish and Portuguese islands in the Atlantic Ocean are not included.

Species occurring only in the saline or brackish parts of the Baltic, Black and Caspian Seas are not included. Species are only included if the record is based on individuals with locality data and identification we feel are reliable.

Introduced species are included only if they have established self-sustaining populations, or if they are regularly stocked at the same localities.

Conventions. Macedonia refers to the Former Yugoslavian Republic of Macedonia (FYROM); the adjective Macedonian may refer to FYROM or the Macedonia Region of Greece, depending on context. Kosovo is treated as a distinct geographic entity. Ireland refers to the whole island, including Eire (Republic of Ireland) and Northern Ireland.

Toponymy (names of places, rivers, etc.) follows the spelling in local languages or transcriptions as used in local maps. For features extending across areas where different languages are spoken, the English name of that feature (if any) is used. For example, we use Rhine and not Rhein

Freshwater fishes

Biogeographers usually classify freshwater fish according to their tolerance to salt water. **Primary division families** are those *families* whose members are strictly intolerant of salt water, both currently and historically; examples include Cyprinidae, Cobitidae and most siluriform families. **Secondary division families** are those *families* whose members now live in freshwater but are able, or supposedly were once able, to tolerate seawater for a short period; they are supposed to be of marine origin; examples include Cottidae, Lotidae and Valenciidae.

In addition to these categories that apply to *whole families*, many species occur in freshwaters that belong to mainly marine families; they are termed as follows:

– **diadromous species** are those *species* that migrate between fresh and seawater at different periods of their life, either to spawn in the sea (catadromous, like the eel *Anguilla anguilla*) or in freshwater (anadromous, like the salmon *Salmo salar*);

– **vicarious species** are non-diadromous, strictly freshwater *species* of primarily marine families; examples are freshwater shad *Alosa agone*, the blenny *Salaria fluviatilis* and many Gobiidae;

– **sporadic species** are those *species* that seem to be indifferent to salinity (i.e. euryhaline) and usually occur in estuaries; examples are many species of Mugilidae and the pipefish *Syngnathus abaster*;

– **accidental species** are those normally marine *species* that are very occasionally caught in inland waters; their occurrence is not predictable and there are usually only a few records of the species in freshwaters; an example is the record of the flatfish *Citharinus linguatulus* from Skadar Lake.

Further reading. Myers, 1938, 1951.

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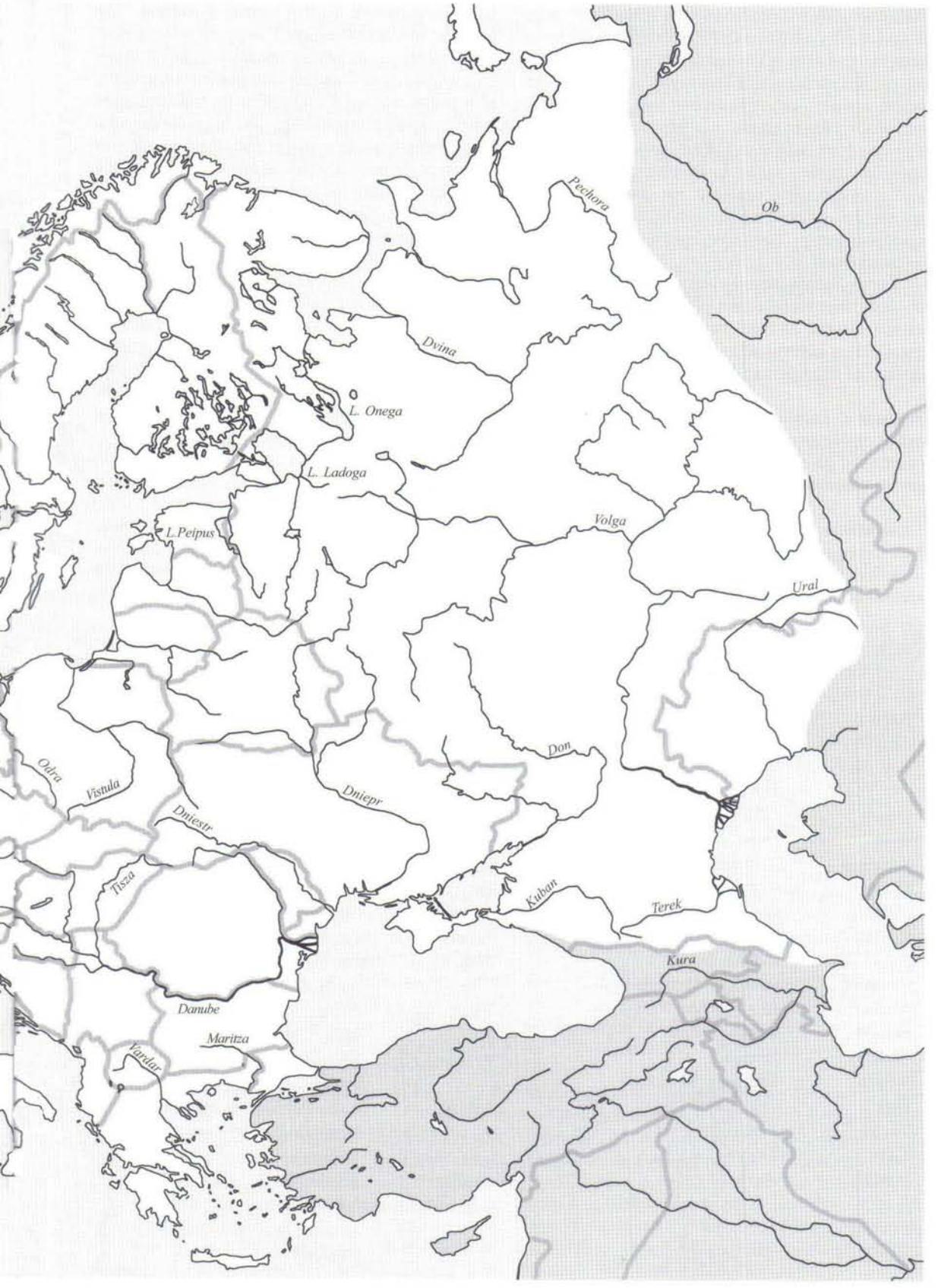
Europe (white) as recognised in this book.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Dniepr
Tisza
Kuban
Terek
Kura
Danube
Maritza
Vardar

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(German), Rhin (French) or Rijn (Dutch). If there is no (or only a little-used) English name, or if we refer only to part of the feature in a given country, we use the name in that country; if we refer to the whole feature, we use the name best known internationally (for example, we use the Greek Aoos instead of the Albanian Vijose) or the name in the language of the country in which most of the feature is situated (for example, we use the Bulgarian Maritza instead of the Greek Evros and the Turkish Meriç). The table below gives a list of equivalences.

For countries, regions, large islands, large cities and other well known places, we use English names instead of local names (for example, we use Corsica instead of the French Corse, Bavaria instead of the German Bayern).

Sequence. Families are listed in the systematic order of Nelson (1994). Brief introductory accounts are given for each family, including diagnostic characters.

Limitations of this book. While we have field experience in several geographic areas and have travelled in 24 European countries during the preparation of this book, we certainly do not claim to have investigated all the species ourselves. The political situations make it impossible to undertake fieldwork in several countries. In other areas, biologists or fisheries administrations are very efficient at making it impossible for outsiders, and often even insiders, to study the local fauna, be it only to photograph a single fish. As a result, our treatment of some species is based largely on the published data (or the lack of it) and our own evaluation of the reliability of this data. In many cases, unfortunately, the data is poor, incomplete, unreliable, or based on dubious methods or concepts.

Anyone writing a guide covering a geographic area the size of Europe has to a great extent to rely on the literature. For some areas or groups there have been detailed recent studies and monographs; for others, information is scattered in the scientific or popular literature, in a multitude of national or even more local languages (we have seen literature in 33 languages), and is often difficult to access. For some species, the information is old, or very old, or restricted to a few or even a single publication vaguely describing the morphology. It may seem odd in 2007 to refer to publications of the 19th century for data on some of the Salmonidae and Coregonidae, but these were the

Toponymy used, and alternative names used locally or in international literature

Rivers	
Aoos	Vijose
Danube	Donau, Dunaj, Duna, Dunav, Dunarea
Douro	Duero
Drin	Drim
Kalamas	Thiamis
Maritza	Evros, Meriç
Meuse	Maas
Nestos	Mesta
Odra	Oder
Resowska	Rezvaya, Rezovska
Rhine	Rhein, Rhin, Rijn
Schelde	Schelt, Escaut
Soca	Isonzo
Struma	Strymon, Strumica
Tagus	Tejo, Tajo, Tage
Tevere	Tiber, Tibre
Tisza	Theiss
Vardar	Axios

Lakes	
Bienne	Lac de Bienne, Bielersee
Como	Lario
Garda	Benaco
Geneva	Léman, Lac Léman, Lac de Genève, Genfersee
Constance	Bodensee, Bodan
Lugano	Ceresio
Maggiore	Verbano, Lake Locarno
Morat	Lac de Morat, Murtensee
Neuchâtel	Lac de Neuchâtel, Neuenburgersee
Pamvotis	Ioannina, Jannina
Peipus	Lake Chudskoe, Lake Peipsi
Prespa Lakes	Mikri Prespa and Megali Prespa
Pskov	Lake Pskovskoe, Pihkva [including Lake Teploe, or Lammijarv]
Skadar	Scutari, Shkodora
Vierwaldstätter	Vierwaldstättersee, Lake Lucerne, Lac des Quatre Cantons

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Characters, character states and traits

A character is any of the morphological, ethological, molecular, etc. features that may be used to diagnose a taxon. A character state is any one of the alternative conditions a given character may have; it is fixed in the species, and thus present in all individuals. For example, 'interorbital pores present' is not a character but a state of the character 'presence or absence of interorbital pores'.

A trait is a genetically determined feature that is not fixed in a population, so different individuals may show different traits of a given character. Different traits of the same characters may be present in different combinations in different species or populations. For example, presence, absence, width, shape, etc. of a vertical bar at the caudal-fin base may all be traits of the character 'mark at caudal-fin base'. In this case, different combinations of the traits of a given character may be different states of that character. For example, species A may have the bar absent, broad, or vertical in different individuals and species B may have it always present, but either as a broad bar or oval blotch.

only published sources of information on their general morphology that could be located.

A very serious problem with the literature (especially recent work) is that many authors uncritically rely on earlier data, many reviews are merely compilations of old, often incompatible data, and that many national and international guides are more or less copied from earlier ones. Errors are thus propagated over long periods of time, even if they have been corrected decades ago in the scientific literature. Figures are often 'adapted' from earlier ones, themselves based on still earlier ones, with more care for the aesthetic value (or the avoidance of plagiarism) than for the reality of nature.

HOW TO USE THIS BOOK

Keys. For families with several genera in Europe, identification keys to the genera are included. Keys to species are provided for genera where this is convenient or feasible on the basis of characters easily observed by non-specialists, without recourse to dissections or sophisticated techniques; a lens or dissecting microscope might be needed. An identification key is a set of questions that allow the user to establish the identity of an individual fish. A key is made of a series of couplets (numbered 1, 2, 3, etc.). Each couplet includes two alternative sentences (numbered 1a and 1b, 2a and 2b, etc.). Each sentence includes one or several statements. The two sentences of a couplet always describe alternative conditions of the same character(s).

To use a key, start at couplet 1. Start by reading sentence 1a and sentence 1b. If several characters are described in a sentence, read all characters. Now decide which sentence describes your fish. Each sentence ends by an indication like 'go to 2' or 'genus X'. If the sentence that applies to the fish you want to identify ends in 'go to 2' this means that you should now read couplet 2 (again, both sentences) and repeat the operation until you obtain a name for your fish.

Example. Let's take the following imaginary key:

1a – Two dorsal fins. 2
1b – One dorsal fin. 4

2a – Second dorsal fin with 7–8 rays. ..... Y
2b – Second dorsal fin with 18–25 rays. 3

First read couplet 1 (both sentences 1a and 1b). Look at your fish. How many dorsal fins does it have, one or two? If it has a single dorsal fin, go to couplet 4. Let's imagine it has two dorsal fins: go to couplet 2. Now read the two sentences of couplet 2. The second dorsal fin is made of a number of rays. Count them. If your fish has, let's say, 20 rays in the second dorsal fin, go to couplet 3. Let's imagine that your fish has 8 rays in the second dorsal fin; then the key tells you that it is a member of genus Y.

When running a key, it may happen that a given species satisfies the conditions of both sentences of a couplet or appears twice in the key. Let's imagine you reach the following couplet:

6a – Depth of caudal peduncle 20–26 % HL. 7
6b – Depth of caudal peduncle 25–44 % HL. 10

Imagine that the material in front of you has a caudal peduncle depth 21–28 % HL. Analysed more precisely, it may turn out that only very few individuals have a caudal peduncle depth less than 25 % HL; if so, go to couplet 10. But if individuals with a caudal peduncle depth less than 25 % HL appear frequently or constitute the majority of the population, then both couplets 7 or 10 should be tested.

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Valid names and valid species.

Confusion sometimes arises from the use of the adjective '*valid*' in two different contexts: 'valid name' and 'valid species'.

In taxonomic (nomenclatural) discussions, a **valid name** is the correct name (as defined by the International Code of Zoological Nomenclature) that must be applied to a species. A **valid species** is a species that exists in reality and is recognized (diagnosable) as opposed to a species that had been hypothesised to be distinct but does not exist, or is no longer recognized, or is treated as a synonym, etc. The term *established species* has been proposed to replace *valid species*, but we do not consider it appropriate as: 1) it creates confusion with introduced, established (naturalised) exotics; 2) a valid species may be ignored by most authors and thus the epithet established cannot be justified.

Therefore we prefer to use *valid*, always followed by *name* or *species* to avoid any ambiguity.

The key does not work! Why? It may happen that a key does not work. For example, it may lead you to a species completely different from the one you are trying to identify (of course you started by looking at the figure), or it may ask questions, which cannot apply to your fish (for example, the number of scales while your fish is devoid of scales). There are a number of possible explanations:

1) You may have an aberrant (malformed or deformed) individual; some characters may have been lost as a result of damage or injury; or your fish may be a senescent individual with an abnormal shape or a juvenile that has not yet developed the diagnostic characters. Try to check these characters in another individual.

2) You may be trying to identify a species not included in the book. The fish fauna of Europe is still incompletely known and species unknown to the authors at the time of writing certainly exist; or you may have an introduced species, or a species escaped from aquaculture or aquarium. Try to consult a specialist.

3) You may have made an error. Try again from the beginning of the key.

4) There may be an error in the key. If this is the case, we do apologize.

The published data on some groups (especially of Coregonidae and Salmonidae) is so poor that the keys we provide may prove to be unsatisfactory.

Names. All names used in headings are the valid scientific names according to the International Code of Zoological Nomenclature. The names may differ from those used in other books. These differences are justified by the Code and have been explained in separate scientific publications.

For a few species that present identification problems, the word 'cf.' (for the Latin 'confer', meaning 'compare') added between the genus and the species names indicates a species that looks similar to a named species but apparently represents a distinct, unnamed species. For example, *Salmo* cf. *cettii* indicates that the species is similar to *S. cettii*.

Some species have not yet been given a scientific name. This is usually because they have only been discovered or recognized recently. When we encountered such cases, we made names available for them in a series of scientific communications published in parallel with this book. In a few cases this was not possible, either because establishing the identity of the concerned species requires clearing very complex nomenclatural and systematic problems, or because other researchers are presently working on these problems. Such species are listed as 'sp.', followed by an indication of its area of origin (e.g. *Rutilus* sp. Sperchios) or some other feature. There are a few cases of unnamed species not effectively being investigated but which we were not permitted to examine by authors intending to work on them: unfortunately, these must remain unrecognized here. It is considered unethical to name a species on which another researcher is working; but we consider it just as unethical for a researcher to block work by others for decades; this may also seriously compromise the conservation future of a species.

Vernacular names (common names) present a variety of problems. First, there are several dozens languages and many more local dialects spoken in Europe. Second, many species do not have a vernacular name (we mean a real one, in local use by ordinary people, not one coined by scientists especially for a technical glossary) and are only called by a collective name; for example, most cobitid and nemacheilid species are collectively called loaches in English, loches in French, schmerlen in German, etc. Further, most of these names are used only in a given region and are unknown elsewhere; for example, in a few square kilometres of northwestern Switzerland *Cottus gobio* is known in the local French dialects as chabot, chavot, tchabo, tchevo. Worse is when an identical name is used for different fishes in dif-

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ferent areas; for example, *Salmo ohridanus* is called belvica in Lake Ohrid, but the name belvica is used for *Alburnus belvica* in adjacent Lakes Prespa. Unsurprisingly, names mentioned in academic literature or legal documents may be totally unknown to local people.

We have tried to give a single name for species with a wide-ranging distribution. If they have an effectively used English name, we list that name as the vernacular name. For example, *Tinca tinca* is the tench. For species known from a single country, or from an area where a single official language is spoken, the vernacular name is the name (if any) in that language. For example, the vernacular name of *Zingel asper* is apron, as this is its name in France and the French-speaking part of Switzerland; the vernacular name of *Ladigesocypris ghigii* is gizani as this is its name on Rhodos Island, the only place where it occurs. We tried to follow this rule but had to make many exceptions for species frequently appearing under an established English name, or when we were not sure that 'local name' appearing in glossaries are really used, or to introduce some consistency within a genus, or for species whose name in the local language is a compound or a complex name (for example, *Salmo rhodanensis* is called Rhône trout and not 'truite du Rhône'). Similarly, difficult-to-pronounce names or those that appear illogical in the particular context are not used. Nor are local name that are mere translations of the scientific name or very recent academic creations. We see no advantage to introducing or forcing English names as 'vernacular' names.

While the case of species with either very wide or very restricted ranges is simple, that of species occurring in areas where several languages are spoken is more complex. In some cases, we favour one language, for example if the range only marginally overlaps the range of a language (for example, the vernacular name of *Rutilus aula* is triotto from the Italian and not mazenica from the Slovenian). In other cases, we escaped chauvinist arguments in resorting to English names. We have often used names proposed by earlier authors, but we have not hesitated to create new ones when we felt that the earlier ones were unsatisfactory. For example, we do not see why *Cottus poecilopus* should be called Alpine bullhead when it is not known in the Alps or in any body of water flowing from the Alps. As much as possible, we have avoided using personal names as part of a vernacular name (for example, *Romanogobio kesslerii* is the sand gudgeon and not Kessler's gudgeon).

For vernacular names of non-English origin, we retain the spelling in the language of origin (or its transcription for names in a non-Latin alphabet). Readers should keep in mind that the pronunciation of some letters in the original language can be very different from the standard Latin pronunciation (and even more from the standard English pronunciation) (for example, letnica is locally pronounced letneetsa [lɛtnɪtsa in International Phonetic Alphabet]). Vernacular names are not written with an initial capital, unless they are named after a place or a person.

Diagnosis. A diagnosis is the summary of characters permitting recognition of a species. Diagnoses include only characters that are useful to identify the species and, whenever feasible, focus on those allowing identification in the field, without dissection and without special equipment (but a magnifying lens may be necessary to check characters on smaller species or individuals). There usually are many more characters differentiating species than listed here, but we selected those that are easiest or most reliable to use. In some cases, a single character may suffice to identify a species, but in many cases, a combination of characters is needed. If a fish is compared to the diagnosis and is found to agree with some of the characters and disagree with others, conclude that the specimen does not belong to the diagnosed species. Very often, it is possible to identify species at a glance, from general appearance, but general appearance is usually very difficult to put into words.

Each diagnosis starts with a sentence stating explicitly that the species is distinguished from a group of other species (the **comparison group**). The size of the comparison group varies, depending on the context, and thus the value of the characters varies. For example, if the comparison group is made of 'all species of the genus known in Scandinavia', this means that the diagnosis cannot be used to identify a fish obtained from outside Scandinavia as some species outside Scandinavia may share the same characters but be distinguished by additional characters not listed here. However, whenever it is possible without entering into too many technical detail and without writing too long and cumbersome a diagnosis, the comparison group has been extended as widely as possible. It may consist of 'all species of the genus' (that is, the diagnosis works also to distinguish the species from congeners not occurring in Europe), 'all species of the family', 'all species of the family in Europe', 'all species of the genus in the Balkan Peninsula', 'all species of the genus in Europe', etc.

The different characters are separated by slashes (/) and each character is preceded by a symbol that indicates the 'efficiency' of a character for the identification of a species within the compari-

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son group: ● means that this character is not observed in any other member of the comparison group and that its presence alone allows identification of the species; ○ means that this character is shared with some (not all) species of the comparison group, thus that its presence alone does not permit identification of an individual fish and so it is the combination of all stated characters, which distinguishes the species.

A few words of caution:

1) For reliable identification, it is better to check several individuals of a species as the possibility of abnormal individuals can never be ruled out.

2) The inventory of the European fish fauna is not complete so that the likelihood of finding species not yet recorded from a given country or from a given drainage, or not yet recorded in the scientific literature, exists, especially in species of small size or with restricted habitats in remote areas.

3) Although the introduction of exotic species is now widely recognized as an extremely serious threat to our native fauna and is forbidden in most countries, it does still occur, deliberately or accidentally in European waters, with many European species continuing to be translocated from basin to basin.

4) In case of doubt as to whether a character is really unique to the species being diagnosed, we have arbitrarily rated characters as ○ instead of ●. Unless they are unambiguously distinctive, we have usually not rated fin-ray counts, scale counts and morphometric characters as ● because they are often close to those of other species (or some overlap may be expected), and ambiguities are possible with slightly different ways of counting and measuring.

Sizes are usually given as standard length (SL) (see Morphological features, below) and correspond to the largest recorded size, based on the literature or on personal observations. This information should be treated with caution because, for several large or rare species, the actual maximum size is likely to be significantly larger than that recorded in the literature. Some sizes are given as total length (TL). The terms fork length and body length are not used in this book.

In order to save space in the diagnoses, the adjectives dorsal, adipose, caudal, pelvic, anal and pectoral are used as nouns (unless otherwise required for clarity) and mean dorsal fin, adipose fin, caudal fin, pelvic fins, anal fin and pectoral fins, respectively. Bilateral symmetric structures are written in the singular (e.g. the eye is large, and not the eyes are large), unless syntax or common sense require a plural. In descriptions male and female are used at the singular.

Distribution. General native distribution in Europe is given first (where accuracy is needed basins or other details are given). This is followed by summarised global distribution of the species, and places at which it has been introduced. Inclusion of an area or a country under distribution does not mean that a species is evenly distributed within this area but is only meant to provide general information on distribution.

We use a hierarchy of the words basins, drainages, and systems to describe the hydrographic networks. **Basin** is used for seas and lakes, **drainage** for rivers (usually large rivers) reaching the sea (e.g. Danube, Rhine) and **system** for individual tributaries within a drainage. The basin of a sea comprises the network of water bodies emptying into it, excluding the marine habitats themselves. By using this hierarchy, we hope to lighten the style of some paragraphs, making the text easier to understand for readers unfamiliar with the toponymy of a given area. This also eases some linguistic problems resulting from the adaptation to English of a multilingual toponymy. Some linguistic problems cannot be avoided. In several languages, the names of lakes and streams include words describing the category of the feature, making transliteration awkward (for example, we could not avoid using phrases like 'Lake Chiemsee' although 'Lake' is redundant as Chiemsee already means 'Lake Chiem' in German). Some features will be known to everybody (e.g. the Mediterranean Sea, River Danube) and 'River' and 'Sea' have been omitted whenever possible.

Habitat. Habitats of larvae, juveniles and adults might be very different and some species are known to shift between different habitats during the year. Habitat use is also influenced by a large spectrum of abiotic and biotic factors such as water temperature, competition, and predation.

To give detailed data on habitat use and ontogenic or seasonal habitat shifts is beyond the scope of this book. In most cases we simply mention whether a species lives in streams, rivers or lakes and whether it inhabits the upstream or downstream parts of rivers, the deeper or shallower parts of lakes, and pelagic or littoral habitats. We only mention dramatic habitat shifts. In migratory species, habitats in the sea and in lakes as well as in rivers, are mentioned. We provide some notes on the landscapes where a species usually occurs, such as mountain lakes or lowland rivers. If available, information on spawning habitats is given.

Rivers are large natural streams, with tributary streams, that end in the sea. They are usually distinguished from streams by their larger size, a flow of more than 50 m^3/s on average. Lakes resulting

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from the impoundment of streams and rivers are called reservoirs. In lowland situations, larger streams and rivers change their course, thereby creating backwaters, which constitute a continuous succession from riverine conditions to densely vegetated water bodies completely cut off from the river. Old crescent-shaped meanders connected to the river only during high floods are called oxbows. Strictly speaking, the word pond should refer only to water bodies that may be emptied by humans. We use this word here in a less strict sense for small and shallow, artificial or natural water bodies; the distinction between ponds and lakes is not always clear, and we reserve the word lakes for deeper and larger water bodies having a true pelagic zone.

Biology. Of course, it is impossible to summarise here all the available information on the biology of a given species. On the other hand, there is a desperate lack of even the rawest baseline biological data for most species and for most areas; this is obvious for (but not restricted to) small-sized species and southern Europe.

This paragraph usually starts with the reproduction biology of the species, with data on age at first spawning, how often females spawn each season and how many years they reproduce, and basic data about the spawning season, time and behaviour. Spawning is triggered by water temperature and day length in most species and, if available, we indicate the temperature at which spawning starts. The spawning period varies greatly with latitude and altitude and a species, which spawns in early March in southern Europe, may start to spawn in late May in the very north of its range or in montane habitats. In the southern part of its range a species may spawn several times each summer, while it will spawn only once in the northern part. For example, in central Europe, *Barbatula barbatula* spawns from April until September, while in the northern part of its range or at high altitudes, females spawn only once a year. In that particular case, the southern populations have shorter lives and reproduce for only a single season, whereas the northern ones may spawn for several years.

For species with large ranges, most of the available data are derived from central European populations. We tried to summarise not only these data but also to include information on the marginal areas.

Temperatures (given as °C) always refer to water temperatures, unless explicitly stated otherwise. The word temperature is usually not used, but use of °C implies water temperature.

The Biology section usually ends with the type of food consumed. It is impossible here to list quantitative or detailed qualitative data on food taken. In most species there are no adequate data to correlate the kind of food taken with the available prey organisms and therefore, most species seem to indifferently prey on invertebrates of an appropriate size. However, there is a strong correlation between the observed food and the available food items, between prey size and the size of the fish, as well as between the available foods and the differences in predation risk a foraging fish takes when searching for different kinds of food.

Conservation status. The IUCN Red List status is given, followed by a short description of the main threats to the species, if any, and related comments. The status of species endemic to the Mediterranean basin is based on evaluations made during a IUCN workshop held in Malaga (Spain) in December 2004. The status of all other European species has been evaluated when preparing this book, in coordination with IUCN Freshwater Biodiversity Unit. The details of the evaluations are available from the IUCN database (http://www.iucnredlist.org). We reviewed the status of all European species, based on our own observations, data or estimates. For some Mediterranean species, the evaluations made during the Malaga workshop are based on the taxonomic data available at that time. The taxonomy of several species has been reviewed for the present book, requiring an update of their Red List status. Our evaluations have been through the formal IUCN validation procedure, except for a few still waiting for comments of relevant specialist groups of the IUCN Species Survival Commisssion. These Provisional Red List Assessments are marked by asterisks (*). Unnamed species that are in the categories LC or DD are not onto the Red List until they are named and their status is marked by two asterisks (**).

It is important to note that the IUCN Red List is a tool designed to assess extinction risks, and not to determine conservation measures needed or even less a tool to fix priorities. Although designed for use with all organisms, the criteria have obviously been designed primarily with terrestrial organisms in mind, and their application to strictly aquatic organisms is sometimes problematic. This especially applies to the definition of extent of occurrence, area of occupancy, and fragmentation.

Some important definitions: The **extent of occurrence** is the area within the shortest continuous boundary within which the species is known to occur. It is defined as the convex polygon in-

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cluding all the known localities of a species. Of course, for freshwater organisms, this is of little value as they are unable to survive more than a few seconds on dry land; it results in a species restricted to a few coastal swamps around the Mediterranean (e.g. *Aphanius fasciatus*) having an extent of occurrence larger than the whole area of the Mediterranean.

The **area of occupancy** is the area within the extent of occurrence in which the species actually occurs. A species will usually not occur everywhere within its extent of occurrence. For example, it will be absent in unsuitable (or, in the case of fish, terrestrial) habitats. A species may typically occur more or less throughout a whole river basin (there may be vagrant or drifting individuals or isolated individuals washed away by floods and settling downriver in an unusual habitat). The area of occupancy includes only the habitats where the species normally forages and reproduces, and the areas essential for its survival. For example, the area of occupancy of a homing species with an obligatory single spawning ground is the area of that spawning ground, and may be only a few square metres in extent (see also "location", below). In lacustrine habitats, a deep-water species may occasionally be observed in shallow coastal waters; these coastal waters are part of its extent of occurrence, but not of its area of occupancy; the reverse would be true for a benthic littoral species occasionally observed to be pelagic in the middle of the lake.

A **location** (in the Red List context) is defined as a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present. A location may include part of one or many subpopulations. Location should not be confused with locality.

Severely fragmented (in the Red List context) is used when an increased risk to a taxon results from the fact that most of its individuals are found in small and relatively isolated subpopulations.

The categories are:

EXTINCT (EX): A taxon is Extinct when there is no reasonable doubt that the last individual has died. A taxon is presumed Extinct when exhaustive surveys in known and/or expected habitat, at appropriate times (diurnal, seasonal, annual), throughout its historic range have failed to record an individual. Surveys should be over a time frame appropriate to the taxon's life cycle and life form. To our knowledge, this has not been done for any European fish. However, several species are most likely extinct as they have not been recorded for many years (i.e. *Coregonus oxyrinchus*, unrecorded for more than 60 years) or as their habitat is completely lost. Available information leading us to believe that a species is extinct is given in the species' account. [Extinct is used when the species has totally disappeared. If it has disappeared only in part of its range, it is referred to as extirpated].

EXTINCT IN THE WILD (EW): A taxon is Extinct in the Wild when it is known only to survive in cultivation, in captivity or as a naturalized population (or populations) well outside the past range.

CRITICALLY ENDANGERED (CR): A taxon is Critically Endangered when the best available evidence indicates that it meets any of the criteria A to E for Critically Endangered (see below and Table), and it is therefore considered to be facing an extremely high risk of extinction in the wild.

ENDANGERED (EN): A taxon is Endangered when the best available evidence indicates that it meets any of the criteria A to E for Endangered (see below and Table), and it is therefore considered to be facing a very high risk of extinction in the wild.

VULNERABLE (VU): A taxon is Vulnerable when the best available evidence indicates that it meets any of the criteria A to E for Vulnerable (see below and Table), and it is therefore considered to be facing a high risk of extinction in the wild.

NEAR THREATENED (NT): A taxon is Near Threatened when it has been evaluated against the criteria but does not qualify for Critically Endangered, Endangered or Vulnerable now, but is close to qualifying for or is likely to qualify for a threatened category in the near future.

LEAST CONCERN (LC): A taxon is Least Concern when it has been evaluated against the criteria and does not qualify for Critically Endangered, Endangered, Vulnerable or Near Threatened. Widespread and abundant taxa are included in this category.

DATA DEFICIENT (DD): A taxon is Data Deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status. A taxon in this category may be well studied, and its biology well known, but appropriate data on abundance and/or distribution are lacking. Data Deficient is therefore not a category of threat. Listing of taxa in this category indicates that more information is required and acknowledges the possibility that future research will show that a threatened classification is appropriate. It is important to make positive use of whatever data are available. In many cases great care should be exercised in choosing between DD and a threatened status. If the range of a taxon is suspected to

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be relatively circumscribed, and a considerable period of time has elapsed since the last record of the taxon, threatened status may well be justified.
NOT EVALUATED (NE): A taxon is Not Evaluated when it is has not yet been evaluated against the criteria.

The categories **CR**, **EN** and **VU** are defined by quantified criteria:
A Reduction of the size of the population (reduction of the number of individuals, the area of occupancy, extent of occurrence, quality of habitat; increase of exploitation, of pollution, of parasites, of competitors or other stresses; introductions).
B Small extent of occurrence or area of occupancy.
C Small population size related with some degree of continuing decline.
D Very small population size.
E A quantitative analysis shows the probability of extinction in the wild within a short number of generations or years.

For all criteria, the threshold values are different according to the different category levels. The criterias and the values are listed in the Table below.

Remarks. Other information considered of potential interest.

Further reading. References are given to published sources in which more detailed accounts of the species may be found. These are not intended to be exhaustive bibliographies. We have selected the sources that seem most appropriate, that include significant information, provide references to additional publications, critical compilations, etc. In some instances, there may be only a single reference, which is not always very reliable. The topic of the reference is briefly stated in parentheses. References are in the format 'Author, year' or 'Author, year: page'. Page numbers are given only for publications dealing with several topics or several species. Complete bibliographic details are listed in Literature Cited. The sources we used for writing the accounts are usually much wider than those in the Further reading sections.

Figures. Every species is illustrated with a figure in left lateral view, which is the standard in fish taxonomy. Species in which polymorphism is known are illustrated by several figures. The origin and size of the figured individuals are listed, when known. Identification should be based on the characters given in the diagnoses and not only by comparing a specimen with the figures. The general appearance of fishes may change seasonally (spawning, foraging), with size and age, or with environment parameters (e.g., pattern and colour are more contrasted in individuals living in clear than in turbid water). There is also variation between individuals and sexes. Light conditions during photography and the conditions of the individual fishes (alive or dead, fresh or preserved, in or out of water, etc.) have a significant influence on the appearance. It is obviously not possible to illustrate each species under all these conditions, and so we have chosen figures that we hope will best assist diagnosis of the species. While freshly preserved specimens are best for purposes of comparison, the colours of some fish fade or change as soon as they die, sometimes as soon as they are out of the water or even under stress. We have tried not to make this a 'Book of Dead Fish' but instead seek to show live individuals whenever possible. For many species however, photographs of live individuals are not available, or do not exhibit characters useful for identification.

Maps. Maps were prepared by Kevin Smith, Freshwater Biodiversity Assessment Unit, IUCN Species Programme. Most correspond to those in the official IUCN Red List (see http://www.redlist.org). They show the distribution of all species native to Europe, distinguish the present native range (red), areas where they have been introduced or where they are invasive (green), and areas where they are extirpated (blue). For species native to Europe and also present outside, the range around the Mediterranean is figured, but, for technical reasons, it was not possible to show the range in northern Asia. For example, *Hucho taimen* is shown with only a small European range, while in fact it has a range extending from the Urals to the Amur drainage. No maps were produced for introduced species not native to Europe.

The maps are based on our field observations, on the material that we examined, and on information provided by colleagues. They are also largely based on the literature when available. Unfortunately detailed atlasses are available for a few countries only; for most countries there are only rough or simple maps (or no maps) and therefore small errors may be expected.

Montenegro declared independance in May 2006. The maps was already prepared and unfortunately it was impossible to correct the national boundary between Montenegro and Serbia.

Literature cited. The Literature cited section includes bibliographic references only to the works cited in the text. Only published references are used. This means that grey literature (reports, unpublished thesis, etc.) are not included as they are not usually available through library channels.

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Summary of the five criteria (A-E) used to evaluate if a species belongs in category of threat (Critically Endangered, Endangered or Vulnerable) (IUCN, 2001).

Use any of the criteria A-B	**Critically Endangered (CR)**	**Endangered (EN)**	**Vulnerable (VU)**
A. Population reduction Declines measured over the longer of 10 years or 3 generations			
A1	> 90%	> 70%	> 50%
A2, A3, A4	> 80%	> 50%	> 30%

A1. Population reduction observed, estimated, inferred, or suspected in the past where the causes of the reduction are clearly reversible AND understood AND ceased based on and specifying any of the following:

(a) direct observation
(b) an index of abundance appropriate to the taxon
(c) a decline in AOO, EOO and/or habitat quality
(d) actual or potential levels of exploitation
(e) effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites.

A2. Population reduction observed, estimated, inferred, or suspected in the past where the causes of reduction may not have ceased OR may not be understood OR may not be reversible, based on (a) to (e) under A1

A3. Population reduction projected or suspected to be met in the future (up to a maximum of 100 years) based on (b) to (e) under A1.

A4. An observed, estimated, inferred, projected or suspected population reduction (up to a maximum of 100 years) where the time period must include both the past and the future, and where the causes of reduction may not have ceased OR may not be understood OR may not be reversible, based on (a) to (e) under A1.

B. Geographic range in the form of either B1 (extent of occurrence) OR B2 (area of occupancy)			
B1. Extent of occurrence	< 100 km²	< 5,000 km²	< 20,000 km²
B2. Area of occupancy	< 10 km²	< 500 km²	< 2,000 km²
and 2 of the following 3:			

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(a) Severely fragmented or # locations	= 1	< 5	< 10

(b) Continuing decline in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals

(c) Extreme fluctuations in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) number of locations or subpopulations; (iv) number of mature individuals

C. Small population size and decline

Number of mature individuals	< 250	< 2,500	< 10,000
and either **C1** or **C2**:			
C1. An estimated continuing decline of at least:	25% in 3 years or 1 generation	20% in 5 years or 2 generations	10% in 10 years or 3 generations
up to a maximum of 100 years			
C2. A continuing decline and (a) and/or (b):			
(a i) number of mature individualss in all sub-populations:	< 50	< 250	< 1,000
(a ii) or % individuals in one sub-population at least	90%	95%	100%
(b) extreme fluctuations in the number of mature individuals			

D. Very small or restricted population

Either:			
(1) number of mature individuals	< 50	< 250	< 1,000
OR			
(2) restricted area of occupancy	na	na	AOO < 20 km² or # of locations < 5

E. Quantitative Analysis

Indicating the probability of extinction in the wild to be at least:	50% in 10 years or 3 generations (100 years max)	20% in 20 years or 5 generations (100 years max)	10% in 100 years 10% in 100 years

Source of data, data transformation, causes of errors, limitations of data, and a little human psychology

Data used for writing the species accounts originate from various sources. In part they come from our own observation in the field and of live, freshly-preserved or museum specimens. In such cases, we have been able to ensure that the data are obtained in a consistent style. For some species, data were obtained from the literature. In such cases, whenever feasible, we have tried to check these data against material. This was not always possible as some species are not available in museum collections accessible to us. In a few cases, we have not been permitted to access the relevant material.

Different authors may use different methods for measuring or counting scales and rays, or use different terminologies. To allow comparison, it is of course necessary to standardise these data. We note that many recent works merely compile data from various sources and are very misleading because of the uncritical acceptance of the published data and the lack of standardisation.

There are several systems to report morphometric and meristic characters. For some characters (e.g. dorsal or anal-fin ray counts), the translation from one system to an other is reasonably unambiguous. For others, the translation requires an interpretation of the data and some speculation. For example, this may be the case of the lateral line scale counts. We would have preferred to give all of them in a single format (distinguishing the scales on the body from those on the caudal-fin base, e.g. 28–31 + 2–3) but the transformation of total counts (including scales on caudal-fin base) into standard counts would have implied some subjectivity and the introduction of potential errors. We decided therefore to retain the data in the original format and this explains an apparent lack of consistency between some accounts. We feel that the lack of consistency is less damaging than the risk of introducing errors.

In the worst cases, the authors of the sources have not indicated the methods they use; here we were left with no choice but to redo their work on actual specimens (if available) or to resort to the two most sophisticated tools ever developed in scientific research: educated guessing and instinct. Educated guess may introduce fewer errors and less confusion than uncritical compilation from heterogeneous sources.

The quality of the published data is especially poor for salmonids, which comprise the group for which we have experienced the greatest difficulties in obtaining material usable for morphological examination (there would be much to say about difficulties in cooperating with some of the agencies in charge of 'managing' the environment).

It is impossible to describe the total variability of a character. There are always individuals that exhibit anomalous character states because of injuries, health, etc. Very small or very large individuals may have somewhat different appearances and it would be tedious (and space-consuming) to record all these subtleties here. In addition, when measuring fishes, one has to remember that these are not metallic structures but soft tissues, which can be deformed or damaged by the tool, and that measurements of soft tissues are not absolutely replicable. Specimens need to be fixed correctly, and in many cases we know that the material used by original authors was far from optimal.

Whenever feasible, conclusions derived from morphometric characters should be based on a series of specimens not on single individuals. If a diagnosis says 18–23 % and the examined specimen shows 17 %, this does not automatically excluded it from a given species as the sample we have examined may not include the full range of variation present in the species.

Some scale or fin ray counts show very little variability within a population or a species, while in other species they may show variability. Here also, conclusions should be based on several specimens. Unique or infrequent counts have been ignored in the diagnoses (for example, if an author reported having counted dorsal rays in 589 specimens and to have observed 7½ rays in 578 and 8½ rays in 11, we have ignored the low-frequency '8½' value).

There is some belief that *meristic* characters (elements that can be counted, e.g. rays, scales) have a superior diagnostic value than *morphometric* characters (elements of anatomy that can be measured) or than *descriptive* characters (shape, colour, etc.). This is far from true, but probably relates to human psychology and education. Most people feel more confident with countable characters because they are discrete values, they seem easier to compare and they are easier to manipulate electronically in large numbers. Morphometric characters are not discrete numbers, and so need to be transformed before comparison. They give the appearance of being less 'stable' and are more subtle to manipulate. Descriptive characters are often very reliable characters but for many are

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perceived as unreliable not because of the intrinsic value of the character but because of the limitations of the observer's ability to describe shape, colour, structure, surface, texture, sound, etc.; this difficulty is often compounded by linguistic difficulties if the work has to be written in a foreign language. This explains the quasi-religious way in which meristic characters are sometimes presented, often as long ritualised formulae, even if they convey no usable diagnostic information (often the less experienced the author, the greater the weight given to these characters). Different cultures also have different approaches of numbers, accuracy, and this also seems to explain why some authors give more weight to numbers, and others to shape.

MORPHOLOGICAL FEATURES

Terms and methods used for single families or genera are explained in the parts of the text in which they are used. The following concerns terms and methods that are used throughout the text. We follow standard terminologies used internationally in ichthyological research and literature; readers familiar with eastern European literature may experience some difficulties as a result of the development of endemic terminologies and methods during the times when international scientific exchanges were difficult. We strongly advocate adherence to the unitary international terminology and methods, and abandoning the cumbersome and user-unfriendly litany of abbreviations (with upper and lower cases, Roman and italic fonts, Latin, semi-Latin, Greek or other scripts) and the ritual formulae that bedevil the European ichthyological literature, making it impossible to read and comprehend these texts efficiently.

Further reading. Hubbs & Lagler, 1947 (methods); Boschung & Mayden, 2004: 45–60 (methods, terminology).

Measurements. Standard measurements used are illustrated in Figure 1. All these are taken as a straight line from point to point, and neither over the curve of the body nor as projections along the longitudinal axis. *Standard length* (abbreviated

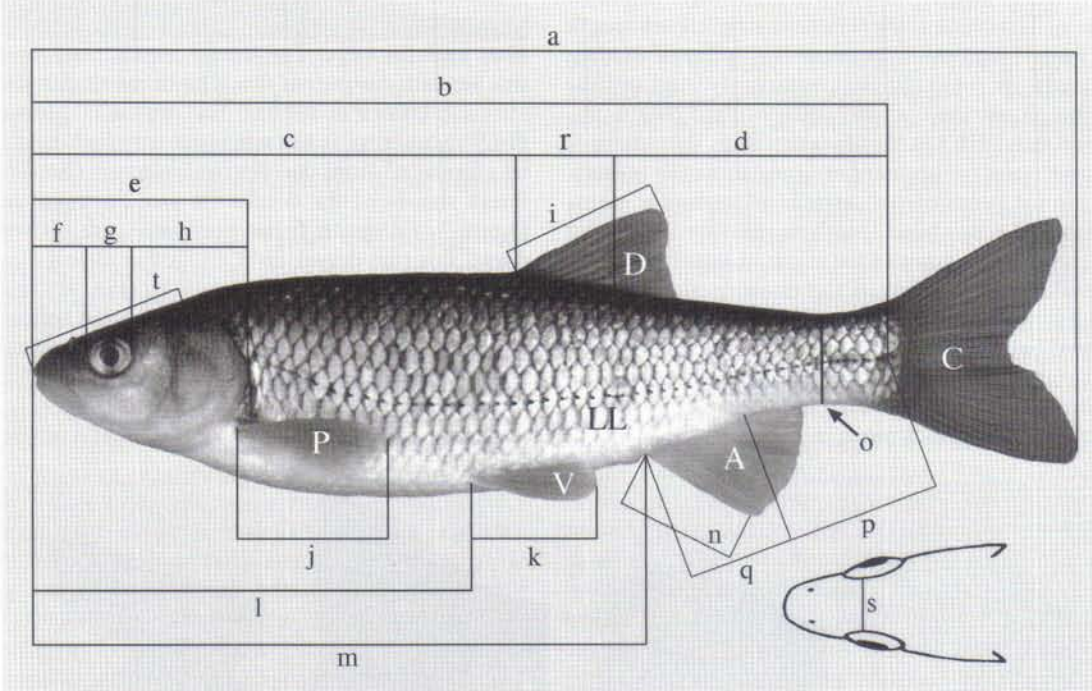

Figure 1 Fins, lateral line and main measurements. All measurements are point to point. **A,** anal fin; **C,** caudal fin; **D,** dorsal fin; **P,** pectoral fin; **V,** pelvic fin (ventral fin); **LL,** lateral line; **a,** total length; **b,** standard length; **c,** predorsal length; **d,** postdorsal length; **e,** head length; **f,** snout length; **g,** eye diameter; **h,** postorbital length; **i,** length of dorsal fin; **j,** length of pectoral fin; **k,** length of pelvic fin; **l,** prepelvic length; **m,** pre-anal length; **n,** length of anal fin; **o,** depth of caudal peduncle; **p,** length of caudal peduncle; **q,** length of base of anal fin; **r,** length of base of dorsal fin; **s,** interorbital width; **t,** dorsal head length.

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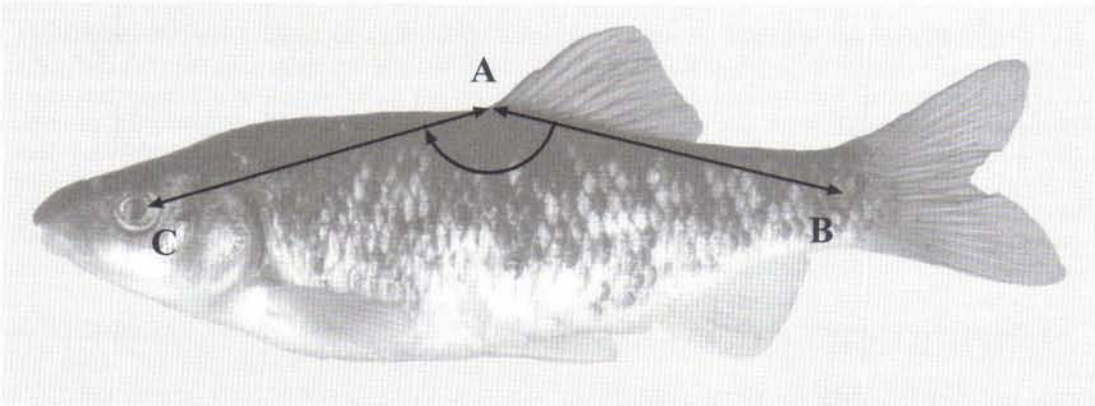

Figure 2 Dorso-hypural distance is measured from origin of dorsal fin to base of median caudal ray (A-B) and reported forward (A-C). A-B = A-C. In this example, dorso-hypural distance reaches almost to middle of eye.

SL) is measured from the anterior-most point of the snout or upper lip to the base of the median caudal rays (note that the base of the caudal fin does not necessarily coincide with the last scales since the scales often extend on to the caudal fin; the base of the caudal fin is easily seen as a crease when the fin is bent from side to side). *Total length* (abbreviated **TL**) is measured from the anterior-most point of the body to the posterior-most point of the caudal fin. In most fishes, SL is used as the reference length; in a few groups (e.g. lampreys, eels) TL is used as the reference length. Fork length (from anteriormost point of fish to tip of median caudal fin rays) although commonly used in fisheries is not used in ichthyology. *Head length* (abbreviated **HL**) is the distance from the anterior-most point of the snout or upper lip to the posterior-most point of the opercle or opercular membrane. Dorsal head length is measured from the anteriormost point of the snout or upper lip to the posteriormost point of the cranium along dorsal midline (occiput). Except for standard length and total length, which are given in mm, all other measurements are given either as a percentage (for example as % SL or % HL) or as a ratio (for example, head length 4 times in SL).

The length of the caudal peduncle is measured from the base of the posterior-most anal ray to the base of the median caudal rays; its depth is measured at the narrowest point (the 'minimum body depth' of eastern European authors). The dorso-hypural distance used for some species of Cyprinidae is measured from the dorsal-fin origin to the base of the median caudal ray; it is usually reported forward from dorsal-fin origin and reaches some landmark along the dorsal profile (behind eye, at nostril, tip of snout, etc.; Fig. 2).

Fins and fin rays. The dorsal, caudal and anal fins are called *unpaired fins*. The pectoral and pelvic (also known as ventral) fins are called *paired fins* ('ventral fins' is an ambiguous term and should be eliminated from descriptive biology). The different shapes of the caudal fin are illustrated in Figure 3. European fishes may have one or two dorsal fins (the dorsal fin is altogether absent in a few species). The *adipose dorsal fin* (Fig. 4b) is a small membranous and rayless fin situated behind the dorsal fin and present only in some families. In those fishes that have *two dorsal fins* (Fig. 5), the anterior one often consists only of spines (Fig. 5a) and the second one often consists of a single

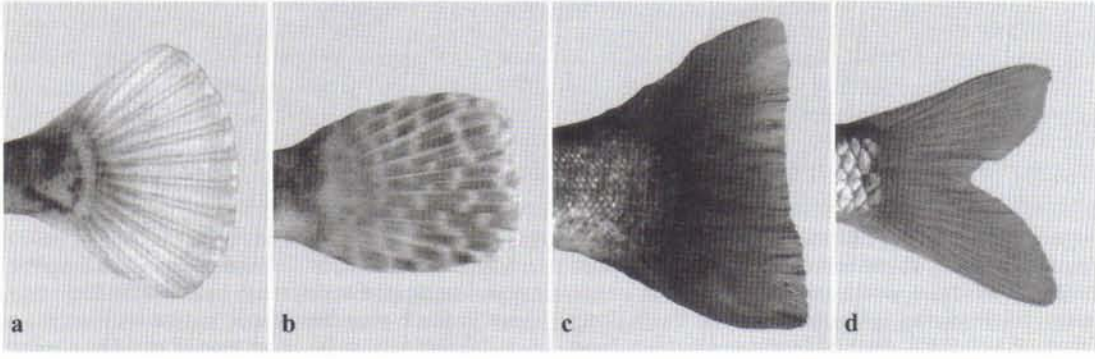

Figure 3 Common types of caudal fin: **a,** rounded; **b,** truncate; **c,** emarginate; **d,** forked.

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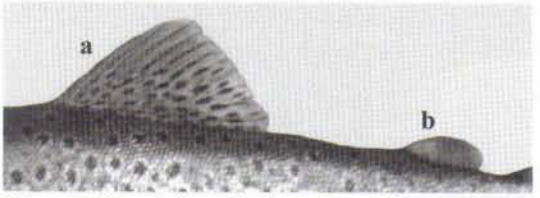

Figure 4 Dorsal fins of salmoniform fishes: **a,** rayed dorsal fin; **b,** adipose dorsal fin.

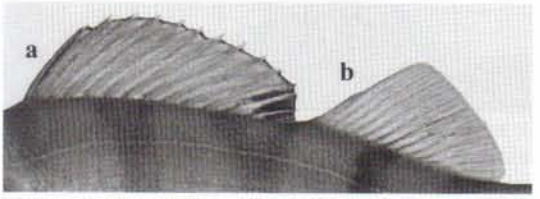

Figure 5 Dorsal fins of perciform fishes: **a,** first, spinous dorsal fin; **b,** second, soft dorsal fin.

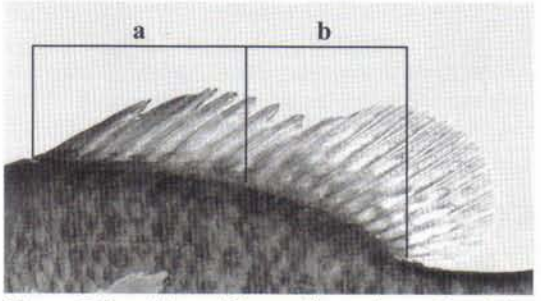

Figure 6 Fused dorsal fins; **a,** first, spinous dorsal fin; **b,** second, soft dorsal fin.

anterior spine followed by soft (or segmented) rays (Fig. 5b); in some families, the two dorsal fins may be fused (Fig. 6).

Anatomically, true *spines* are median (unpaired) structures, never branched, never segmented, generally hard and pointed. *Soft rays* are composed of a right and a left parts, usually *segmented* and *branched* (Fig. 7). In some species (for example, in many Cyprinidae) some anterior rays may be fused into unsegmented, hard and inflexible 'spines', which may also be *serrated* anteriorly and/or posteriorly (that is, with a series of indentations or teeth along the respective margins). Such rays are often qualified as bony or ossified, both inappropriate; ossified means "converted into bone, hardened by deposits of mineral matters", and bony means "related to, resembling, or made of bone"; all rays are made of bone (rigid, semiporous, calcified connective tissue). We retain the adjective 'spinous', one of whose meaning is "resembling a spine, shaped like a spine", to describe these rays, sometimes completed by 'rigid' (not flexible), 'strong' (thick, resistant, hard), etc.

The base of a fin is the region along which it

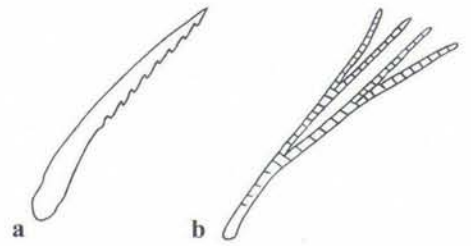

Figure 7 Schematised spine (**a**) and soft, segmented, branched ray (**b**). Spine (**a**) may be smooth or serrated posteriorly (as in figure), anteriorly or on both sides (from Kottelat, 2001b).

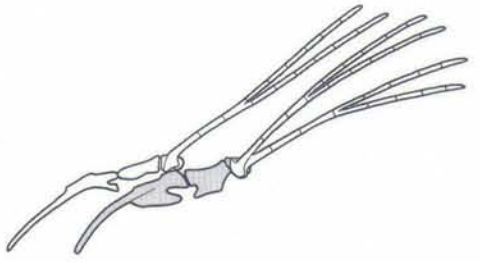

Figure 8 Posteriormost dorsal rays showing the last two rays articulating on a single pterygiophore (gray) (after Roberts & Kottelat, 1984).

attaches to the body. The *origin* of a fin is the insertion point of its anterior-most ray (i.e. the anterior-most point of the base of the fin). The posterior point of the base is sometimes called the insertion, a word not used with that meaning here because we find it semantically erroneous and misleading. The heights of the dorsal and anal fins are measured from the origin of the fin to uppermost (and respectively lowermost) point of the fin. The base of a fin ray is the point it is inserted to the body (in some fishes, part of the rays and membranes are covered by scales, making it uneasy to see the base of the ray).

The respective positions of fins is often given in the form 'dorsal origin in front of anal origin' or 'dorsal origin above pelvic base', meaning that the origin of the dorsal fin on the back is situated in front of a vertical line through the origin of the anal fin, or above the base of the pelvic fin, respectively.

Fin ray counts may include only soft or branched rays, or may include simple and branched rays separately, or may be the total number of rays in a given fin; this is explicitly stated in each case. The last two branched dorsal and anal rays are often borne by a single pterygiophore (the bones on which the rays articulate; Fig. 8). These two rays are counted as '1½'. Thus, 12–

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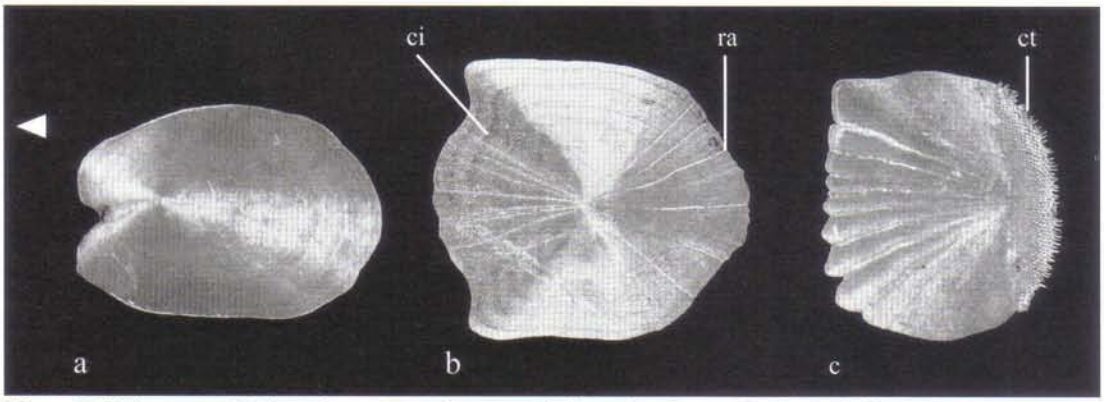

Figure 9 Main types of fish scales: **a,** *Esox lucius*, cycloid; **b,** *Squalius cephalus*, cycloid; **c,** *Sander lucioperca*, ctenoid. **ci,** circuli; **ct,** ctenii; and **r,** radii. Arrow points towards head.

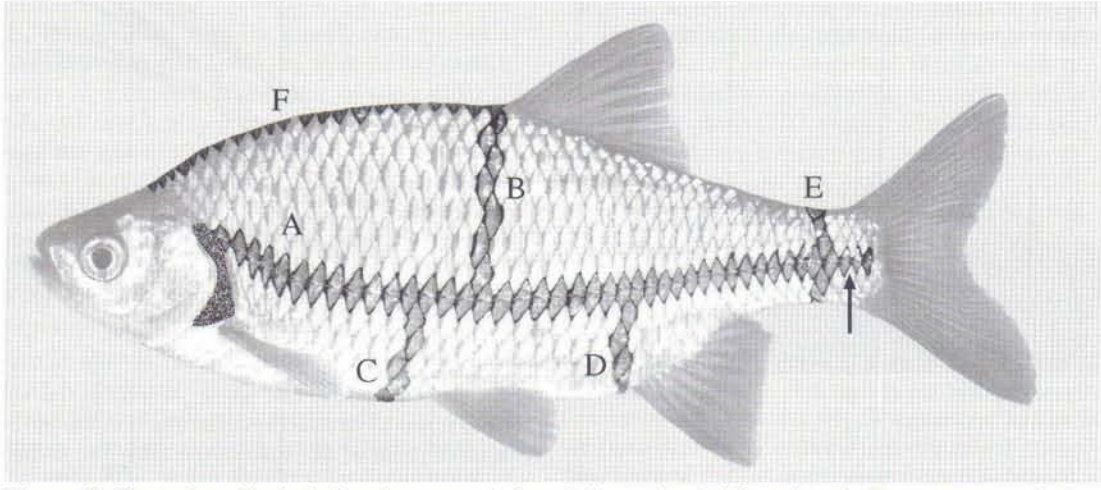

Figure 10 Illustration of principal scale counts. **A,** lateral line scales (midlateral row); **B,** transverse scales between lateral line and origin of dorsal fin; **C,** transverse scales between lateral line and midline of belly, three scales in front of base of pelvic fin; **D,** transverse scales between lateral line and origin of anal fin; **E,** circumpeduncular scales; **F,** predorsal scales. Stippled: shoulder girdle. Arrow: last scale on body and first scale on caudal fin.

13½ branched dorsal rays means that the dorsal fin includes 13 or 14 branched rays, of which the last two share the same pterygiophore (or sometimes appear as a single ray split up to the base). Authors have been very inconsistent in giving ray counts or have often neglected to explain which method they use, so that the same 12–13½ count may appear in the literature as 12–13 if the last two rays are counted as one, or 13–14 if they are counted as two. We prefer the notation using ½ because it makes it instantly evident that the author is aware of the problem with the last two branched rays. '9+8 branched caudal rays' means that there are 9 branched rays in the upper lobe of the caudal fin and 8 in the lower lobe. Usually, there is also a principal unbranched ray above and one below the branched rays, and several rudimentary rays in front, that are not counted.

Scales. Two main types of scales are known in European freshwater fishes: *cycloid* and *ctenoid* (Fig. 9). Cycloid scales have a smooth posterior margin while ctenoid scales have many small projections (*ctenii*) along the posterior margin. Other structures visible through a magnifying glass on the scales are *circuli* (or rings) and *radii* (or spokes), either on parts of the scale or on the whole scale. Sturgeons have a different type of scales (ganoid-like), restricted to the upturned lobe of the caudal fin.

The count of *lateral line scales* (Fig. 10) represents the number of pored scales in the lateral line (unless otherwise stated, unpored scales are not included in the count) or, if the lateral line is incomplete, the number of scales along the line in the position, which it would normally occupy if it were complete; this is termed the *midlateral row.*

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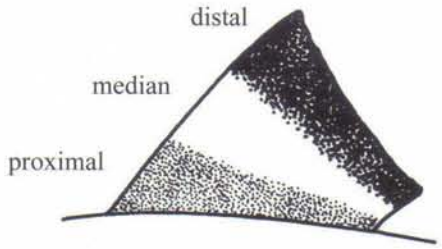

Figure 11 Position of colour marks on fins.

If lateral line pores are absent, the *midlateral series* is the number of transverse scale rows counted at mid-height of flank. The anterior-most scale counted is that one in contact with the shoulder girdle but followed by one, which is separated by another scale from the shoulder girdle. Counts terminate at the base of the caudal fin. Scales on the caudal fin itself are not included, even if well developed and pored; they are sometime indicated by '+'. For example, the lateral line scale count of the fish on figure 10 is noted as 40 + 2: there are 40 scales along the lateral line on the body and 2 on the caudal fin. Some scale counts have been adapted from the literature; many authors do not indicate whether or not their counts include the scales on the caudal fin and some errors may have been introduced while trying to standardise the presentation of these counts in this book. *Total lateral line scale* counts are those derived from the literature where the authors failed to distinguish scales on the body from those on the caudal fin.

Fishes may loose scales, for example when attacked by a predator, during courting or during spawning. This is also observed where fish are frequently handled, for example at sites used for annual censuses or research. Lost scales would usually be replaced but replacement scales often show growth or position anomalies; scales may be deformed, fused, split, displaced, etc. In some species, counts will show very little variability and in others some variability is encountered. When there is great variability, it is usually the case that the scales are small, deciduous, partly embedded in the skin or that scale rows are irregularly arranged; counts should be checked on several specimens and extreme or anomalous counts should be ignored, as well as those based on damaged individuals.

Transverse scale counts indicate the number of scale rows between the lateral line and the origin of the dorsal fin (or the first dorsal fin if more than one) and between the lateral line and the midline of the belly (either in front of the pelvic fins or the origin of the anal fin, depending on the context). If any, the scale on the dorsal and ventral mid-lines (i.e. immediately in front of the dorsal and anal fins) is noted as ½. Example: the transverse scale count for the fish illustrated in Figure 10 is ½7/1/4, ½ meaning one scale immediately in front of the dorsal (predorsal row), 7 scales between the lateral line and the predorsal scale, 1 lateral line pored scale, and 4 scales between the lateral line and the preanal scale. The transverse scale count in front of the pelvic is ½7/1/4½.

The *predorsal scale count* includes all the scales on the dorsal mid-line in front of the origin of the dorsal fin (usually between the occiput and the dorsal-fin origin; 22 on Fig. 10). Predorsal scales are sometimes difficult to count exactly as the rows are not always regular (as at level of scales 1–3 on Fig. 10).

Circumpeduncular scale counts represent the number of scale rows crossing a line around the caudal peduncle at its narrowest part (12 on Fig. 10, with a transverse count of ½2/1/2½).

Colour marks. *Bars* are vertical marks. *Stripes* are longitudinal marks. Other elongated marks are called bands. Usually, more or less round marks about the size of the pupil or smaller are called spots, smaller ones dots and larger ones blotches, but there are some inconsistencies, especially when round marks of different sizes are present; then spots means smaller marks and blotches larger marks. On the fins, a proximal band is located

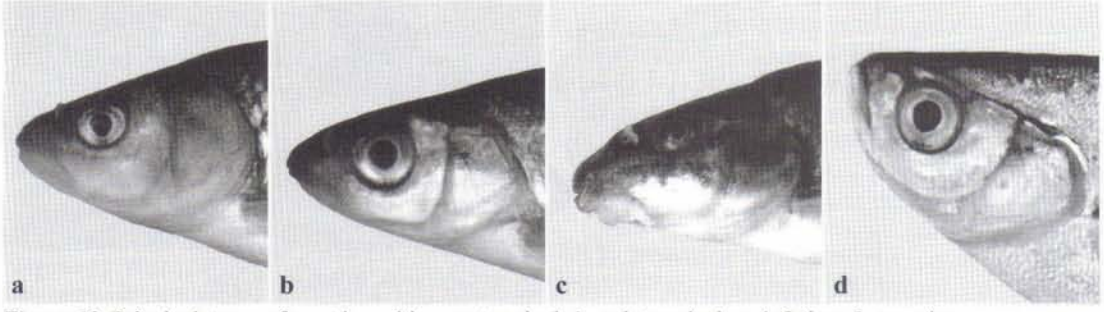

Figure 12 Principal types of mouth position: **a,** terminal; **b,** sub-terminal; **c,** inferior; **d,** superior.

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Species, populations, ESUs

The species is the 'currency unit' of most fields of biology and it is not surprising that its definitions and concepts have been (and will always be) the subject of much debates. The following is only a succinct summary of some of the basic concepts.

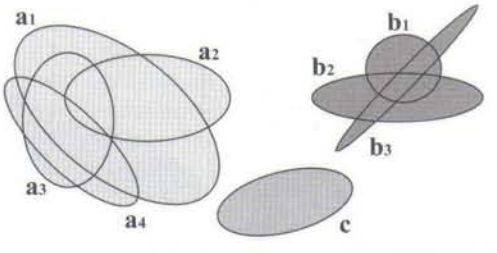
The species concept we try to follow is the **Evolutionary Species Concept** (ESC): the species is an entity composed of organisms that maintains its identity from other such entities through time and over space and that has its own independent evolutionary fate and its own historical tendencies.

Species are individuals in nature, they participate in natural processes, they change over time, they have an origin and may give rise to other species (speciation), and they will have an end (extinction). Of course, the future of a living species cannot be predicted, but we know they will have a fate; the concept also applies to fossil species, and we know they had a fate. Because species are individuals, they cannot be *defined* and it cannot be expected that all members of a species will conform exactly to a definition. But, as individuals, species can be *described* and *diagnosed*, the lineages can be identified, and the changes over time can be observed (given enough time and appropriate tools). Experience shows that most characters do vary, usually in a way that can be more or less empirically predicted (this implies the availability of both time and experience) and it is therefore not surprising that most diagnoses include exceptions and overlap with other (usually allopatric) species.

Species are known from samples of specimens and samples of characters. The homogeneity of a sample can be tested empirically. Sometimes not all individuals are identifiable as a given species; sometimes they can be recognized only during part of the life cycle, or only individuals of one sex can be identified, etc. In some cases it may be difficult to distinguish if differences between two populations are the result of phenotypic adaptation to particular environmental conditions or of evolutionary adaptation, which are genetically fixed.

There is concern that the use of the ESC combined with the rise of molecular techniques could result in recognizing thousands of isolated, postglacial, lacustrine communities of *Perca fluviatilis, Rutilus rutilus* or *Coregonus albula* as distinct species on the basis of minute molecular differences.

In taxonomic discussions, a **population** was originally understood as a segment of a species whose members breed mostly or solely among themselves, usually resulting from physical isolation. This definition implies that species are diagnosed before groups of individuals within the species can be labelled as populations. The pitfall is to distinguish whether two groups of individuals are two populations of a single species, or two species. The commonly accepted criterion was that there is gene flow between populations of a species but not between species, but there is a large number of exceptions and nuances, so that generalities should be avoided and cases examined one by one. As a matter of fact the definitions of the words 'population' and 'species' have evolved in a not always coordinate way and sometimes leaving a gray zone between them, especially if fine-resolution molecular methods are applied. Therefore, the rule of the thumb among taxonomists is that molecular characters should be used very carefully and only if congruent with some other set of characters (morphological, ethological, etc.). There is some sort of continuum in the variability of the different populations of a species, while there is some sort of hiatus between the respective variabilities of two species (see figure). The difficulty remains, of course, to link the theory and the facts observed in nature.



Schematic representation of the variability of characters, showing overlap in different populations of two species (**a1-a4, b1-b3**) and hiatus between three species (**a, b, c**).

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Textbooks still often refer to the **Biological Species Concept**, although it has long been abandoned because it is not operational. It can be applied to determine the distinctness of species only if the species occur in sympatry, thus only for a trivial number of species on earth as allopatric speciation is the most common mode of speciation. Most species/populations for which we need to decide on distinctness or not live in allopatry, and this is even more pronounced for aquatic biodiversity. In fishes, this concept is useful to demonstrate that distinct groups of fishes (e.g. coregonids) occuring together in the same lake are species because they keep their identity in sympatry.

Hybrid fertility is often believed to be the one criterion to decide whether two populations are conspecific or not. This is an outdated approach. In fishes, hybrid infertility appears at very different ages in different lineages and even within one lineage. Within some groups, species that separated 2–15 MY ago are still able to produce fertile offspring while, in other groups, species that separated much more recently are no longer able to produce fertile hybrids. This is observed, for example, if there are chromosome incompatibilities as in loaches of the genus *Cobitis*. In fishes, hybrid infertility is infrequent at the species level, but usually observed at the genus, subfamily or even family level.

Evolutionary Significant Units (ESU) is a concept developed out of a legal need in the U.S.A. to identify threatened 'populations' in order to grant them legal protection. An ESU is "a sub-portion of a species that is defined by substantial reproductive isolation from other conspecific units and represents an important component of the evolutionary legacy of the species". The use of this administrative category in scientific debates and its use outside the U.S.A. are logically and politically questionable as it is defined by U.S. legislative instruments. In Europe, ESU has been used at times with a similar understanding as in the U.S.A., but in recent years confusion arose as the 'word' ESU has been appropriated by molecular biology and used with radically different definition and weakening its conservation aim. These authors see ESUs as substitute to species. For them, any mitochondrial evolutionary line would be an ESU, which certainly is not the aim of the original concept. Further, this ignores that mitochondria are regularly transferred between species by introgressive hybridisation and, often, are not congruent with species. Often, the recognition of ESUs merely highlights the absence of modern taxonomic investigation.

Further reading. Cracraft, 1989 (Phylogenetic Species Concept [PSC]); Waples, 1991 (ESU); Mayden & Wood, 1995 (ESC, ESU); Mayden, 1996 (hierarchy of species concepts); Kottelat, 1997 (PSC and European fishes); Kullander, 1999 (species); Wiley & Mayden, 2000 (ESC); Mayden, 2002 (species as individuals).

along the base of the fin, a distal band along the outside margin of the fin, a median band in the middle of the fin (Fig. 11); subdistal and subproximal bands are located in intermediate positions.

Others. Nomenclature for mouth positions and gill-arch structures are given on Figures 12 and 13, respectively. *Gill rakers* are the forward bony projections usually present on the four anterior gill arches; there is a different number of rakers on the different arches of the same individual and all the counts given here refer only to the outer gill rakers on the first (anterior-most) gill arch on the right side. The count includes all gill rakers including distinctly formed rudiments, unless otherwise stated. It is sometimes indicated as A+B+C, where A is number of gill rakers on the upper limb (hypobranchial), C on the lower limb (ceratobranchial) and B at angle between the upper and lower limbs (if any). It is sometimes necessary to cut out and remove the gill arch to count the gill rakers. In ichthyology, dissections are always made on the right side to keep the left side intact for identification, photography, etc.

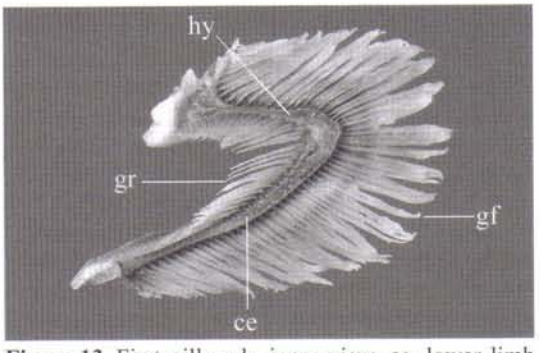

Figure 13 First gill arch, inner view. **ce,** lower limb (ceratobranchial **); gf,** gill filaments; **gr,** gill rakers; **hy,** upper limb (hypobranchial).

Maxillary barbels are located above the upper lip or above the upper jaw (see Fig. 30); *mandibular barbels* are located on the lower jaw or at the corner of the mouth; a *nasal barbel* is a barbel-like extension of the anterior nostril (most fish have a nostril on each side of the head, each with an anterior and a posterior nares).

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TAXONOMY AND NOMENCLATURE

Taxonomy is the theory and practice of describing the diversity of organisms and ordering this diversity into a system reflecting evolutionary relationships among these organisms. To give names to objects and living beings appears to be natural and important for humans because it allows them to communicate with others. This explains why most things, which play a role in their life, positive or negative, have been given names. Animals are no exception. Each language, each country has its own set of names. In order to reach a high level of precision, zoologists developed a nomenclatural (naming) system that gives one (and only one!) name to every different animal species. The current system was first developed by Carl Linnaeus (1707-1778) and the tenth edition of his *Systema naturae* published in 1758 is taken as the starting point of modern zoological nomenclature. This system is now governed by a set of rules known as the *International Code of Zoological Nomenclature* (hereafter the Code), which is revised from time to time, the last revision being in effect from 1 January 2000. This code prescribes a system of naming, which is of vital importance to all biologists because unambiguous communication depends on it. For example, it is important when discussing the results of two studies to make sure that they use a single name for the same species, and that this name is not used for any other species. An International Commission on Zoological Nomenclature (which derives its function and power from the International Union of Biological Sciences) is responsible for amendments to the Code and may be appealed to clear special or conflicting cases. In such cases, the Commission may issue mandatory rulings on names of animals.

Each species has a name consisting of two words, a generic name (in first position, starting with a capital letter) and a specific name (in second position, starting with a lowercase letter), e.g. *Telestes souffia.* Each combination of two words is unique, being given to a single animal species. The generic name indicates affinities (or relationships) with other species: for example, many species of chub-like fishes share the same generic name *Telestes,* indicating that they are quite similar and share a common ancestor in the phylogenetic (evolutionary) history of the group. Some genera (the plural of genus) are termed monospecific and include only a single species. The subspecies is a category no longer used by most modern ichthyologists (the subspecies category is not defendable under the Evolutionary Species Concept and the limits are arbitrary under other species concepts), but it can still be seen in some books; a third name was formerly used to indicates that a fish belonged to a geographically more or less distinct form of a species (e.g. *Telestes souffia agassii*).

The name of a species is often followed by a combination of one or several person names and a year (e.g. *Cyprinus carpio* Linnaeus, 1758*).* This is the author of the first description (formally called the *original description*) of the species and the year in which this description was published. The publication year is the year in which a name satisfied all the conditions set by the Code to be considered available; a name first posted on the internet may not be available until special conditions are met, for example the production of a paper version. When the author name is given without brackets, it means that in the original description the species was placed in the same genus as it is still today. If the author name is given in brackets, it means that the species was originally placed in another genus. For example, *Sander lucioperca* (Linnaeus, 1758) was originally described by Linnaeus in 1758 as *Perca lucioperca.* The indication of the author name does not indicate any kind of property but is merely a bibliographic reference: using the author name and year it is possible to trace the scientific publication in which the original description was published. Mention of the author and year of a name is not obligatory and is justified only in publications dealing with formal nomenclatural or systematic aspects. It is unnecessary in publications related to environmental science and its inclusion often increases burdens and errors when authors and editors do not understand or ignore the rules. Due to layout constraints, authors' names are not used in the species accounts below but are listed in Appendix. We also wish to de-emphasize the importance erroneously given to the unneeded citation of authors' names in non-taxonomic literature.

Genera are grouped into families (names mandatorily ending in -idae), and families into orders (names ending in -iformes) according to their evolutionary affinities. Some families are divided into subfamilies (names ending in -inae) and some orders into suborders (names ending in -oidei). Other intermediate categories (subgenera, subtribes, tribes, supertribes, etc.) are not used in this book (and indeed rarely used in zoology).

Many readers will notice that the nomenclature used in this book is sometimes different from that used in earlier books. These changes are explained in a series of scientific publications written while preparing this book. This does not mean that the older books were wrong: rather, as time passes, new scientific discoveries are made, new

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concepts appear (and sometimes die) and our understanding of evolution and relationships among species evolves; this evolution of our knowledge is reflected in changes to the names given to some species. New discoveries certainly still await us, and so the nomenclature in this book too is likely to be altered in the future. Ideally, the system will be perfected one day, but only when we know everything about fishes. That day is unlikely to come in our lifetime!

The zoological nomenclature system is quite dynamic, in order to allow the incorporation of new results of scientific research. Examples of results that have to be incorporated into the system are:

- the discovery of new animal species or even genera and families, which need to be given names: the Code includes provisions on how the names have to be created;
- the discovery that some species in a genus actually belong to another genus or even represent an entirely new genus; again, the Code includes provisions on how the names have to be treated;
- the discovery that two different names had been given to a single species, for example, one name to the male and one to the female; such names are called *synonyms*; the Code has provisions, which rule that the earliest proposed name (*senior synonym*) has to be retained (this is the principle of priority);
- the discovery that two different species have inadvertently been given exactly the same name; such names are called *homonyms*; the Code has provisions that the earliest named species (*senior homonym*) has to retain the name while the junior homonym has to be replaced (this, again, is the principle of priority).

In this book, we have adopted the latest nomenclature known to us (with the condition that possible changes be justified by biological data and the nomenclature rules) as at 31 March 2007. Based on today's scientific knowledge these are the valid (correct) names; other names are no longer valid and should not be used.

At the time of the first formal naming of each species, a particular specimen is designated as the 'name-bearing type' (usually shortened to 'type'). This specimen is a kind of nomenclatural standard for a name. It does not mean that all individuals of a species will be exactly identical to the type, but that this specimen is used to 'anchor' the name to the particular species to which it belongs. For example, when it is realised that a given 'species' (X) is actually made of two or more species (X1, X2, ...), the species to which the type belongs is the one that will retain that given name X and the others have to be recognized under other names (Y, Z, ...). The locality where the type has been collected is known as type locality. Natural history museums are repositories of types and ensure their permanent conservation.

Non-systematists usually find the type concept an awkward creation, especially because they misunderstand it as if it were the model of an idealised species, which it is not. Types are merely name-bearers and do not provide any definition, diagnosis or description of a species. Nomenclature is a technical issue, not a biological issue.

Further reading. International Commission on Zoological Nomenclature, 1999 (Code); Melville, 1995 (history); Kottelat, 1997, Kottelat & Freyhof, 2007b; Kottelat et al., 2005 (nomenclature of European fishes).

PRESERVING FISHES

With a little experience, and especially with some knowledge of the fauna of a given area, most fishes can be identified alive. But it is sometimes necessary to bring specimens to the laboratory for a more detailed examination or to send them to a specialist to confirm the identification. Fish taken out of the water are often already dead or will die soon, unless special equipment is available. Anyway, it will usually be necessary to sacrifice the fish for examination. It is preferable to fix the fish immediately in the field to ensure the best possible condition of the specimen, and thus an optimal identification (a fish forgotten in a plastic bag, with fins damaged by other fishes, and which died of suffocation, and was fixed several hours after death is often difficult to identify and useless for a museum collection or scientific research).

Fixation is the preparation of a specimen with chemicals (preservatives) to prevent decay and to allow later examination and long-term preservation and storage, for example in a natural history museum. Good fixation of freshly-caught specimens is very important for correct identification. Formalin is the *only* fixative that should be used. Ethanol does not result in a good fixation for identification and long term storage. Formalin is a 35–40% aqueous solution of formaldehyde (a gas). Formalin should first be diluted 1:10 with water (to obtain a 4 % formaldehyde solution); use clean water from the river or lake where the fishes have been obtained. For fixation, use a bucket or a large container in which the specimens will lie flat with all their fins stretched out. Large series of individuals (even several species) from the same locality can be fixed in the same container but an adequate volume of fluid should be available.

When working with preserved fishes, care

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should be taken to prevent formalin from coming into contact with one's skin or eyes. If contact should occur, then the affected part should be washed *immediately* with copious quantities of clean water. Contact with the eye results in an immediate, intense feeling of burning. Containers in which fishes, especially large ones, are being fixed should always be water-tight and kept out of the reach of children and domestic animals. Smoking while working with formalin is best avoided. Formaldehyde is carcinogen and should not be inhaled. Forceps should be used; rubber gloves will be damaged by formalin.

Live fishes should be placed in formalin immediately after collection. Do not transport them for any length of time in a plastic bag or other containers as the stress caused to the fish can result in the loss of colour and thus make identification more difficult, not to mention the possibility of losing the fishes or having the larger ones eating the smaller. There may be local or national regulations concerning the killing of fishes. An anaesthetic is generally impractical under most fieldwork conditions. Alternatively, the fish may be placed in a plastic bag with a little water, and the bag and content frozen as quickly as possible (in a freezer, but without deepfreezing the fish); the fish can then be fixed in formalin. If a fish dies in a bent position or with an open mouth, remove it from the formalin, rinse it abundantly, bend it straight or close its mouth, then return it to the formalin bath; be careful to avoid inadvertently removing scales.

When killed in formalin, fishes may splash for a few seconds -or longer for large, very strong species. This is when the risk of accident is greatest. Act carefully, protect your eyes (glasses do not protect you from a splash of formalin), put covers on containers, keep children, adults and animals at least 2 metres away. Always work near water (either near the river, flowing water or a large bucket of clean water) and immediately thoroughly rinse any tool coming in contact with formalin. Never introduce formalin into a room or vehicle with air conditioning.

Larger fishes (more than 15–25 cm long, depending on body shape and width) should be injected with pure formalin in the abdominal cavity. Alternatively the body should be cut open, slightly to the right side, to allow a prompt fixation of the inner parts.

When fixing fish from a market, one should ensure that the fins are extended at the beginning of the fixation process, when the tissues are still soft. To do this, it is often necessary to place the fish on a piece of soft material, with all the fins stretched and extended with the use of fine needles. Formalin is then poured into the container. The needles can be removed when the tissues have hardened, usually in a few minutes. Alternatively, the fins can be stretched open with forceps and pure formalin brushed over them (for example, with forceps and a formalin-soaked tissue); fix one fin first; after a few minutes it will harden, then proceed to the next fin, etc.; then place the whole fish in standard 1:10 diluted formalin. Be careful not to inhale formalin gas at any time.

Fishes that have been deep-frozen can be fixed in formalin, but the result will not be as good as with freshly-preserved material. They should first be completely defrosted and the fins must be stretched out before fixation.

Fish from different localities should *never* be mixed together in a single container. A label should be placed immediately in each container with the following information: province, river drainage, river or lake name, locality, coordinates if possible, name of collector(s) and date. The label must always be placed *inside* the container and never glued or fixed on the outside (sooner or later it will fall off and specimens without locality data, or with uncertain locality data, are useless).

Use strong, water-resistant, archive-quality paper and write clearly with a waterproof pigment or archival-quality ink, or soft pencil. Cheap paper without fibers (e.g. photocopy paper) is totally unacceptable as it will disaggregate within minutes. Ball-point pens should never be used. Do not try to save money or time at this crucial stage as it is a false economy.

Fishes should remain in formalin for at least one week. They can later be quickly rinsed in water and transferred to a 70% ethanol solution. Isopropanol or methylated spirits (lamp alcohol) are definitely not suitable as they will change the structure, bleach, dehydrate or harden the fish. Dispose of used formalin properly by diluting it in large quantities of water and throwing it away. Do not throw it away where it could come in contact with humans or animals; used formalin that is no longer completely clear should not be re-used. There may be local or national regulations concerning the disposal of formalin.

When shipping fish samples, if feasible, they are better left in formalin in the original, *leak-proof* containers. This is not possible when shipping them by mail or courrier; then, after a few days in formalin, drain the formalin out and replace it with water. The specimens can remain in this water (that still retains some formalin) for 1–2 weeks without damages. Poor-quality containers should be strictly avoided. Seal each container in a plastic bag and place them in a strong box. If this method is not convenient, wrap the specimens in cheese

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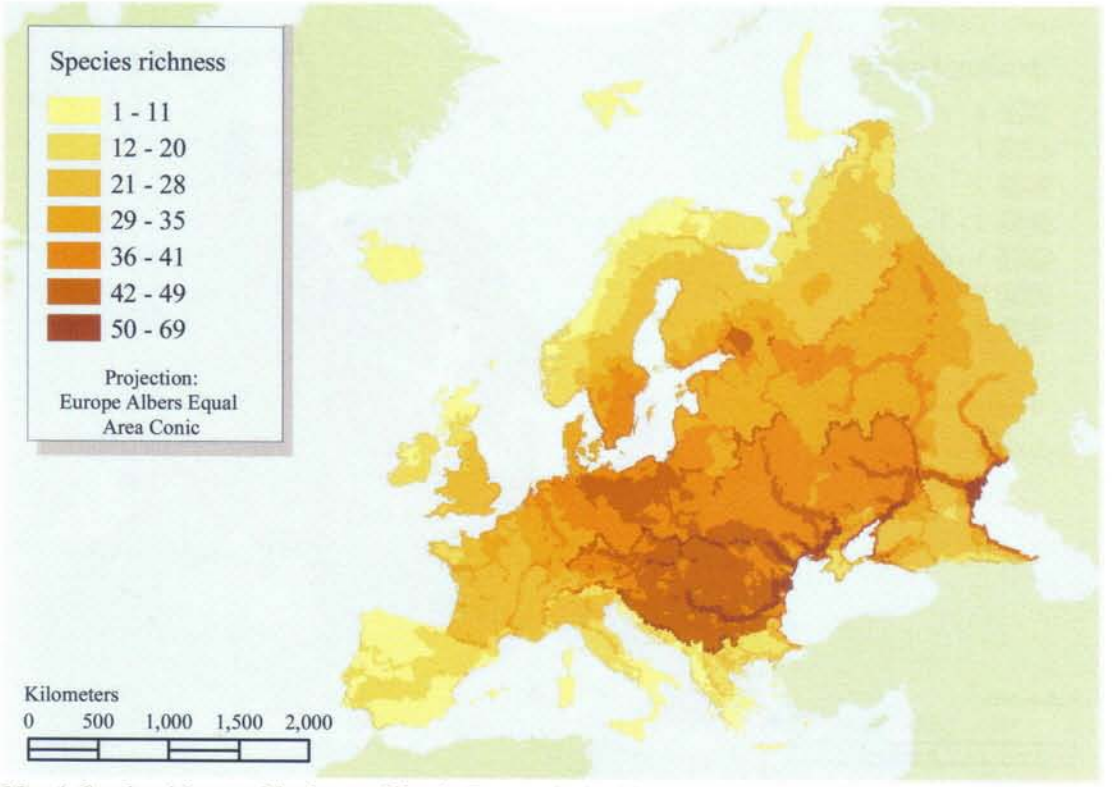

Map 1 Species richness of freshwater fishes in Europe obtained by superimposition of the ranges of 525 species.

cloth or strong white (unstained) tissue soaked in formalin (or soaked in ethanol if the specimens have already been transferred into ethanol), place them in a sealed plastic bag *with the labels inside,* and then place these in a strong box; if the fishes have strong spines, remember that the spines can pierce plastic bags and formalin could leak out. Use several layers of plastic bags and place newspaper, cardboard or polystyrene between them.

CONSERVATION STATUS

Species richness. Using the information from this book it has been possible for the first time to see comprehensive freshwater fish species richness and levels of threat across Europe. The species richness across Europe (native species only) was generated by the superimposition of the distribution maps of 525 freshwater fish species. The number of species was calculated using an hexagonal grid; each hexagon is 287 km^2. Twenty-one species not strictly depending of freshwater at one period of their life-cycle are not included. The highest species richness, between 50 and 69 species, is found in the main channel and delta of the Danube, lower stretches and deltas of the Dniestr, Dniepr and Don and in the Volga delta. Other areas of high fish diversity (between 42 and 49 species) are found in the wider Danube and Dniestr basins, Lake Ladoga, lower Volga and the Elbe, Odra and Vistula (Map 1).

The aquatic habitats of the Iberian peninsula, southern Italy, southern Greece and northern Europe have the lowest species richness. On the other hand, the endemicity rate (ratio of endemic/total number of species) in each European drainage, most of the fauna of the species-poor areas is largely made of endemic species.

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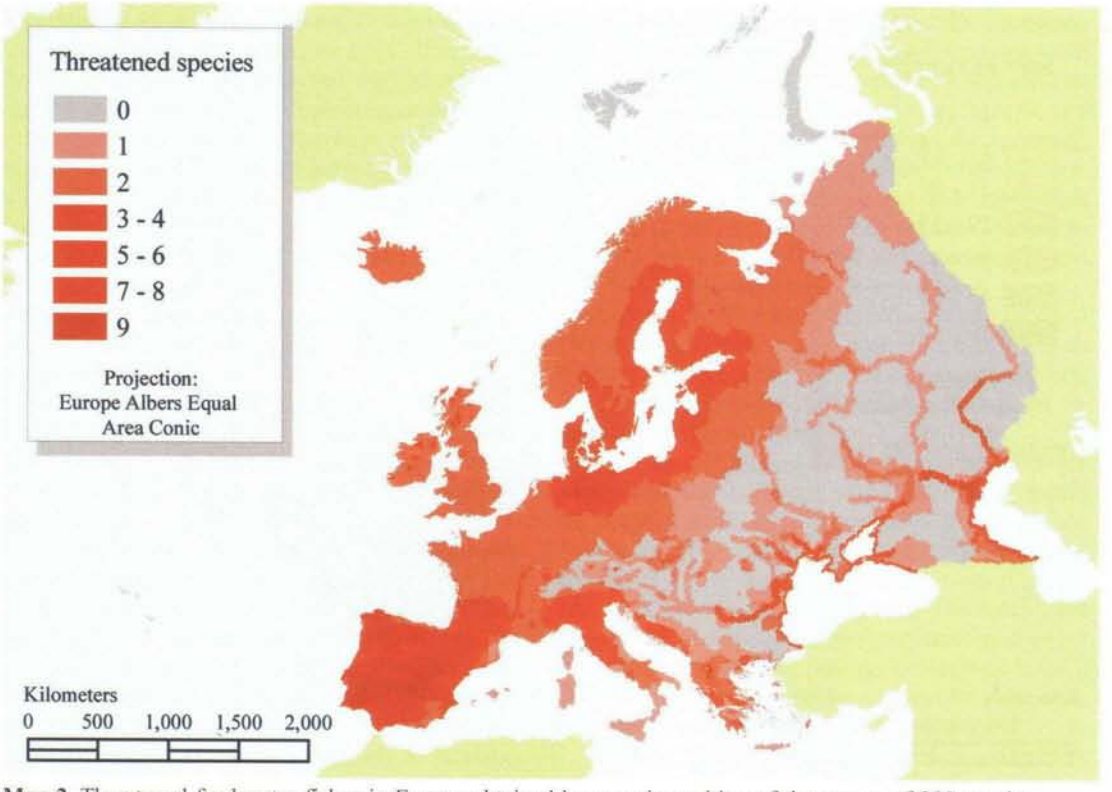
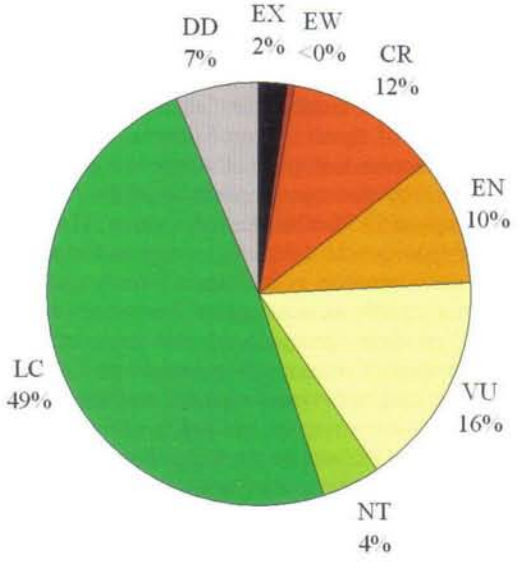


Map 2 Threatened freshwater fishes in Europe obtained by superimposition of the ranges of 200 species.

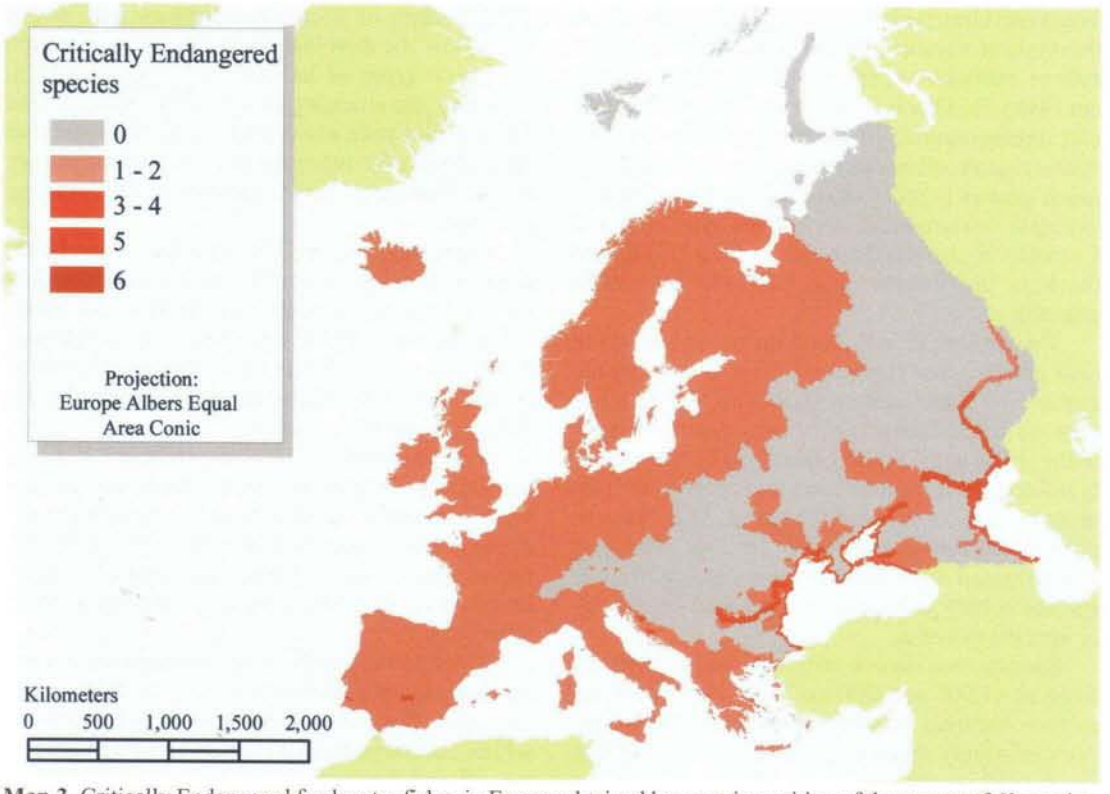


The IUCN Red List status of Europe's freshwater fish species. **EX,** extinct; **EW,** extinct in the wild; **CR,** critically endangered; **EN,** endangered; **VU,** vulnerable; **NT,** near threatened; **LC,** least concern; **DD,** data deficient.

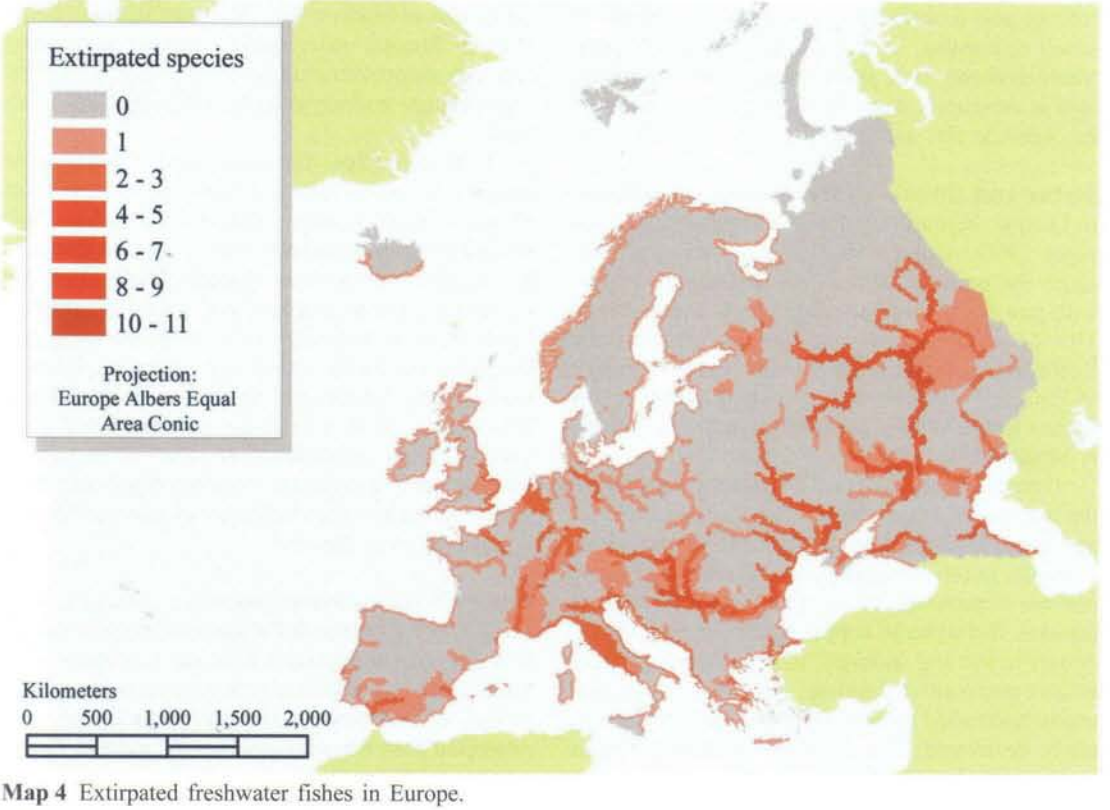
Our analysis shows that 38 % (200 species) of Europe's native freshwater fishes (total 525 included in the analysis) are globally Threatened (those species listed as Critically Endangered, Endangered or Vulnerable using the IUCN Red List Categories and Criteria), with 12 % (62) Critically Endangered, the category with the highest level of extinction risk. 49 % (254) percent are Least Concern, and only 7 % (34) are Data Deficient. Two percent are considered extinct (13 species) and less than 1 % (2 species) are extinct in the wild, meaning the species is extinct in its natural range but now only survives in captivity or in an area outside its original range. Unfortunately, a number of species (e.g. almost all sturgeons) are on the way to the Extinct in the Wild category.

In superimposing the distribution maps of the Threatened Species, the lower reaches of the Danube, Dniestr, Dniepr, Volga and Ural, in the Neretva, Guadiana and Tajo and Lake Prespa and the southern tip of the Crimean Peninsula are the areas where the highest numbers, between 7 and 9, co-occur (Map 2). As these areas are species-poor and with a large endemicity rate, it results that a significant part of the local fish fauna is threatened.

The southern tip of the Crimean Peninsula (Chornaya River), with 6 species, and the lower



Map 3 Critically Endangered freshwater fishes in Europe obtained by superimposition of the ranges of 62 species.



Map 4 Extirpated freshwater fishes in Europe.

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Volga and Ural, with 5 species, are the areas where the highest numbers of species with the highest risk of extinction (Critically Endangered) co-occur (Map 3). This is, however, a somewhat artificial representation, giving more weight to a few wide-ranging, often migratory, species than to the much greater number of small-range species. For example, a significant part of the area with 1-2 Critically Endangered species in Map 3 is due to the huge distribution range of the eel (*Anguilla anguilla*).

The number of extirpated species in any given area parallels the species richness as well as the number of threatened species. The higher numbers are in the main river of the larger tributaries of the Black and Caspian Seas (Map 4). This mainly reflects the impact of dams and other water regulation work on migratory species. This also applies to the Rhône and Rhine drainage. The map of extirpated species also shows extirpation of species in Italy and Spain, in areas with much lower species richness.

Species that have a restricted range (here defined as <1,000 or 5,000 km2) are very important as their survival may be easily compromised by even relatively small impacts (Maps 5-6). These species fall into two gross categories: 1) cold lake endemics, occurring in the Alps, Great Britain, Ireland and Scandinavia; 2) species restricted to small drainages, or sub-drainages, in the peri-Mediterranean area and Crimea. The concentration is especially high along the eastern coast of the Adriatic Sea and in Greece.

Status and threats to freshwater ecosystems. In Europe, human population has almost doubled since 1900. Along with this population growth came the need to feed, home and supply people with power, clothes and other goods and services. This development has had a major impact upon freshwater systems, leading to the loss of over half of Europe's wetlands and providing many serious threats to freshwater fish species and other aquatic biodiversity.

Dams. There has been a massive increase in the number of major dams (reservoir over 15 metres deep) in Europe in the past 100 years, which currently numbers about 3,350. These dams were, and are continuing, to be constructed for various reasons, including to supply water for agriculture, domestic use and industry, to provide power generation and control flooding, which was often naturally controlled by wetlands that had been previously destroyed. The negative impacts of dams include the changing of flow regimes downstream of the dams which disrupt species natural lifecycles that depend upon seasonal changes in flow; the alteration of stream morphology both above and below the dam that results in the suppression of several types of habitats (e.g., rapids, riffles, swamps); the changing oxygen and sediment load of the water both above and below the dam; and they physically interrupt the road of migratory species between their spawning and foraging grounds.

Water abstraction. The draining of wetlands, deforestation of catchments and water abstraction for drinking water, irrigation, tourism and industry, particularly in the dry Mediterranean region, has had severe impacts upon the flow levels in rivers, some of which are now completely dry during the summer months.

Over-exploitation. Over-exploitation of fishes has led to population declines in some species e.g. some sturgeons, salmonids and coregonids. Over-exploitation is often followed by stocking of non-native species, captive-bred individuals, or populations with different genetic or biological characteristics.

Water pollution. Water pollution across Europe has had massive impacts upon the quality of water, often through eutrophication, a process by which excessive nutrients loads from agricultural run-off and domestic waste lead to algal blooms, a depletion of oxygen in the water and a subsequent loss of biodiversity. However, in many countries in Europe water quality is now improving through improvements in wastewater treatment and storage, and agricultural and industrial practices.

Exotic species. Introductions of non-native species is ranked as the second most important threat to biodiversity behind habitat loss. We record 28 established non-native species throughout Europe's freshwater sytems. These often out compete, pass on diseases and parasites, predate upon or even hybridise with native species, and have caused many local native species extirpations. Many species are intentionally introduced for angling, food or aesthetic reasons, some have escaped from aquaculture or released by aquarists, but many species are invasive, expending their range through canals linking two historically unconnected river basins.

Future ? The traditional protected areas approach is often not appropriate for freshwater systems due to the interconnectivity within the whole basin. A stretch of river within a protected area is usually linked up and down stream to areas outside the protected area where many threats, such as deforestation or the introduction of non-native species may be taking place. The same issues arise when rivers cross one or more administrative or inter-

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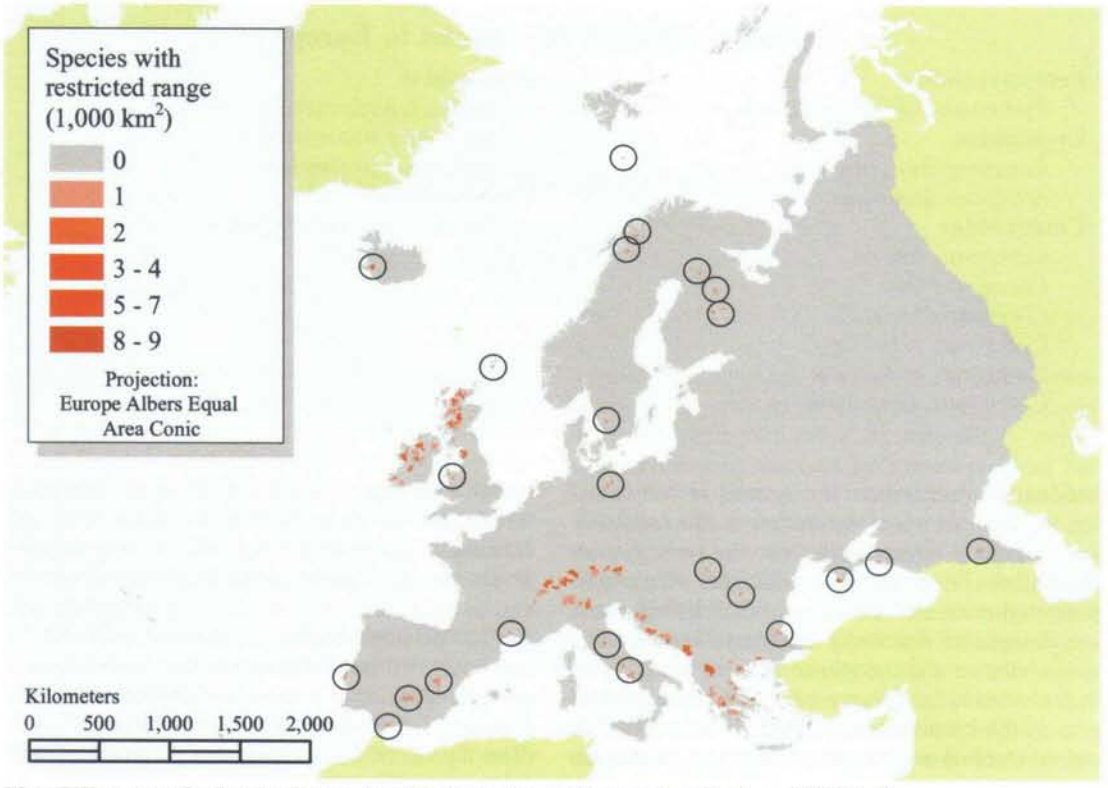
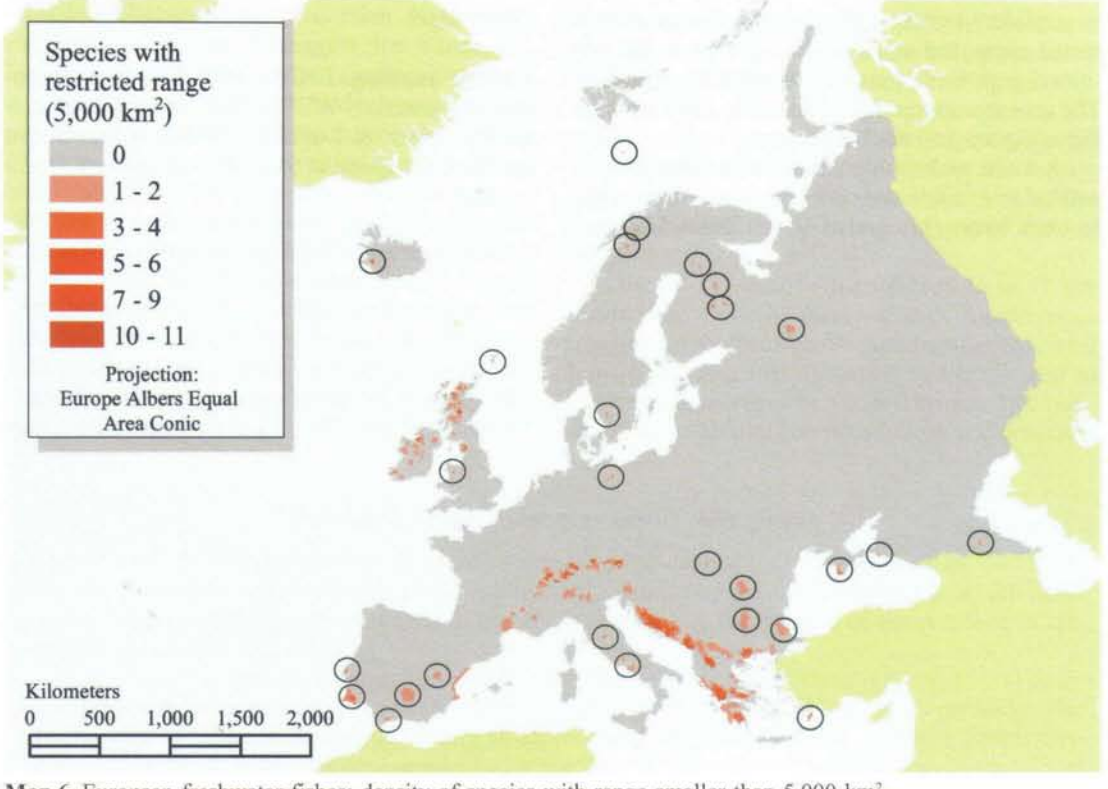


Map 5 European freshwater fishes: density of species with range smaller than 1,000 km².



Map 6 European freshwater fishes: density of species with range smaller than 5,000 km².

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Extinct freshwater fish species in Europe

Petromyzontidae
Eudontomyzon sp. migratory
Cyprinidae
Romanogobio antipai
Alburnus danubicus
Coregonidae
Coregonus bezola
Coregonus fera
Coregonus hiemalis
Coregonus restrictus
Coregonus gutturosus
Coregonus oxyrinchus
Salmonidae
Salmo schiefermuelleri
Salvelinus neocomensis
Salvelinus profundus
Gasterosteidae
Gasterosteus crenobiontus

national borders, where the actions in one country, for example water abstraction or dam construction, can have severe impacts to the river system in another. There are also criticisms of wetland protected areas that are already established, most are designated for water birds and ignore fast-water habitats and rheophilic species. Worst, even in protected areas fish are often not considered as part of the biodiversity but as a commodity that can be stocked and harvested. It is not rare to see exotic species stocked in protected area, for example to support angling tourism. Strangely, this is considered compatible with the status of protected areas; the equivalent would never be permitted with birds (hunting or stocking chicken). The unit to measure fish diversity is still too often the kilogram and not the species.

A multi stakeholder, basin-wide approach is needed to manage and co-ordinate activities within each basin (Integrated River Basin Management). This approach can link activities to impacts throughout the river basin and manage them accordingly. However, this approach does need good levels of information on freshwater biodiversity, and in particular their ecology, distribution and threats. We hope that the information provided by this book will be a valuable tool to help this process, by providing a base line dataset of all the species of freshwater fishes across Europe.
(The figures of this chapter, the geographic analysis and the backbone of the discussion were provided by Kevin Smith, IUCN Species Programme, Cambridge).

Further reading. IUCN, 2001 (Red List categories and criteria); WWF, 2004 (valuation of wetlands); Smith & Darwall, 2006 (Mediterranean species); Dudgeon et al., 2006 (freshwater biodiversity).

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Family Petromyzontidae

Lampreys

Lampreys are not true fishes but constitute a distinct lineage of vertebrates, traditionally associated with fishes. Lampreys are eel-like animals with 7 roundish gill openings behind the eye but without paired fins and jaws. They have a very characteristic oral disc, which they use to attach on to surfaces or to their prey. The dentition of the oral disc is an important character in the identification of genera (Fig. 14).

The life cycle of lampreys is very different from that of fishes. All species of lampreys spawn in spring and usually die shortly after spawning, although a few individuals may survive (up to 5 months reported in *L. planeri*). They go through an eyeless, worm-like larval stage (ammocoete) for several years. The duration of the ammocoete stage is still a matter of discussion. Researches under different protocols suggest that it may last 2½–3½ or 6½–8½ years within single populations in Central Europe. A recent study, however, suggest that they might even need much longer, up to 20 years in *L. planeri*. Therefore, the ages listed below should be considered tentative. Ammocoetes live in detritus-rich sands or clay sediments in freshwater. Depending on species, metamorphosis takes place between late summer and winter; juveniles are always shorter than ammocoetes (larvae shrink during metamorphosis). The juveniles of anadromous species usually migrate to the sea in spring, starting to feed during the downstream migration. Migration is generally nocturnal. After a feeding phase of one to a few years, anadromous lampreys migrate upstream to reproduce in freshwater. Migrating lampreys are attracted by steroidal pheromones released by stream-resident larvae and that function as an indicator of habitat suitability. These compounds are detected at extremely low concentrations and are released in large quantities; laboratory experiments demonstrate that each *Petromyzon* larva activates at least 400 l of water per hour. Upstream migration generally starts in late autumn or early winter and is less marked when temperatures falls below a certain threshold. The peak of upstream migration is usually in early spring. Spawning individuals cease their normal daylight avoidance reaction and reproduce on sunny days. Usually, males arrive first at the spawning sites and then release a bile acid that acts as a sex pheromone, inducing searching behavior in ovulated females. Spawning generally takes place in fast-flowing water, often at the head of riffles in streams. During spawning, the male attaches itself on to the neck of the female and twists its body around that of the female. The female deposits the eggs into the gravel with its belly.

Out of 13 species recognized here, 5 are anadromous (one of them extinct). Anadromous lampreys may form landlocked populations, well known in *Lampetra fluviatilis* in Europe and in *Petromyzon marinus* in North America. Individuals of these landlocked populations are generally

'Parasitic' and 'non-parasitic' lampreys

Lampreys are usually qualified as parasitic or non-parasitic depending on their mode of life. Parasites are defined as species or life stages obligatorily depending on the metabolism on the host. Among the characteristics of parasitism is that the host does not die because of the presence of the parasite, at least not immediately.

Petromyzon marinus does not usually kill its host, but feeds on small amounts of blood and body fluid and remains for a few days or even weeks on one host; it can therefore be termed parasitic. The other species of European lampreys feeding as adults spend only a limited time on a fish, which they usually injure severely or even eat completely before moving to a next one and this does not conform to the definition of a parasite. Therefore, it is more accurate to describe them as predatory. The species that do not feed as adults are called non-predatory.

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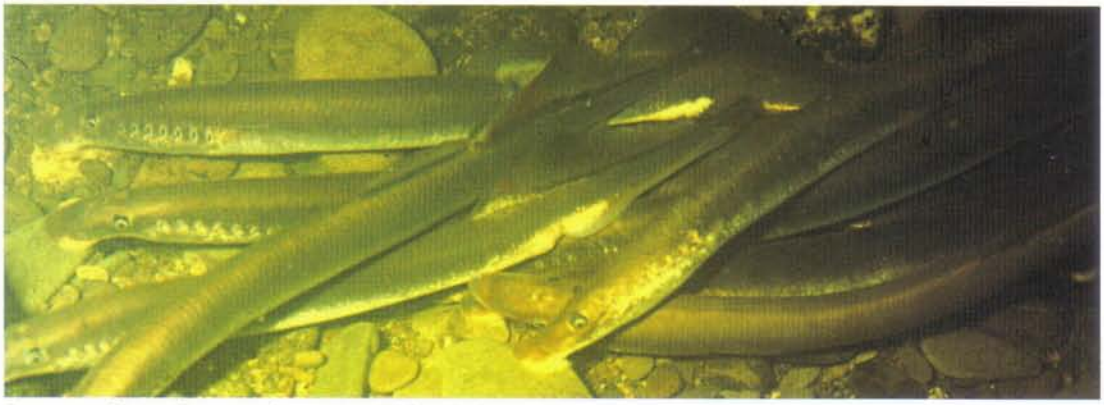

Lampetra fluviatilis; spawning group; Rhine drainage, Germany.

smaller than anadromous ones and have shorter feeding phases, usually lasting only a single summer. Usually, juvenile and adult *Lampetra fluviatilis*, *Lethenteron camtschaticum* and *Eudontomyzon danfordi* live buried in the substrate, waiting for prey to approach, especially at dusk and dawn. They attack fishes and large invertebrates (much smaller than themselves) by sucking with their disc and removing body tissue with their tongue.

The other species have a similar life cycle, but the adults do not feed; they reproduce shortly after metamorphosis and die. Species feeding as adults are parasitic or predatory. In autumn and winter, when they may coexist, adults of non-predatory lampreys are difficult to distinguish from juveniles of predatory ones as both are silvery and may have sharp teeth. The number and size of oocytes are useful in the identification of female juvenile lampreys and large ammocoetes; oocytes are counted in transverse section in front of the first dorsal. Note that all lampreys are protected in most European countries; to check this character the lamprey has to be killed, which implies that the investigator has a serious scientific justification, the technical capacity and the appropriate permits.

There are often pairs of predatory and non-predatory species in sympatry. The best studied case is the relationship between the anadromous, predatory *Lampetra fluviatilis* and the sedentary, non-predatory populations collectively called *L. planeri*. Both have a very similar general morphology. There are indications that, at least in central Europe, the non-predatory lampreys of a given river system are usually more closely related to the sympatric or nearby *L. fluviatilis* populations than to non-predatory populations of other systems.

Petromyzon marinus; Rhine drainage, Germany; ~800 mm TL.

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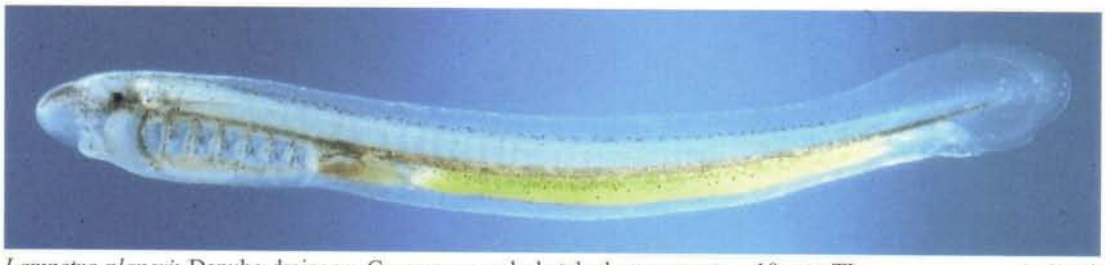

Lampetra planeri; Danube drainage, Germany; newly hatched ammocoete, ~10 mm TL. A. Hartl

Eudontomyzon mariae; Danube drainage, Hungary; ammocoete, ~120 mm SL. Z. Sallai

Eudontomyzon mariae; Danube drainage, Hungary; adult, ~120 mm SL. Z. Sallai

This suggests that non-predatory lamprey might have evolved from *L. fluviatilis* several times in parallel, but this cannot yet be generalised to all non-predatory populations. Because of their size-selected mating behaviour, non-predatory lampreys and *L. fluviatilis* are reproductively isolated at the spawning sites. To date, there is no evidence that the offspring of non-predatory lampreys can evolve the predatory anadromous life-style or that offspring of *L. fluviatilis* can remain in their natal stream and spawn without feeding, but it is possible that this happens in some areas. As *L. fluviatilis* and non-predatory lampreys are able to keep their specific identity in sympatry, they are treated as two species. But clearly, the classification of all brook lampreys as a single species *L. planeri* needs to be re-examined. Generally, non-predatory lampreys are very difficult to identify and the number of species, their distribution and their diagnostic characters are far from clear. Molecular data also suggest that the current generic classification might not reflect the phylogenetic relationships of European lampreys.

Identification of lampreys may be difficult and requires information on their life cycles. Whenever possible, we list only characters that do not require complex dissections.

Further reading. Vladykov & Kott, 1979 (diversity, distribution); Hardisty & Potter, 1971–1982 (biology); Hardisty, 1979 (biology); Gill et al., 2003 (phylogeny); Sorensen et al., 2005 (pheromone).

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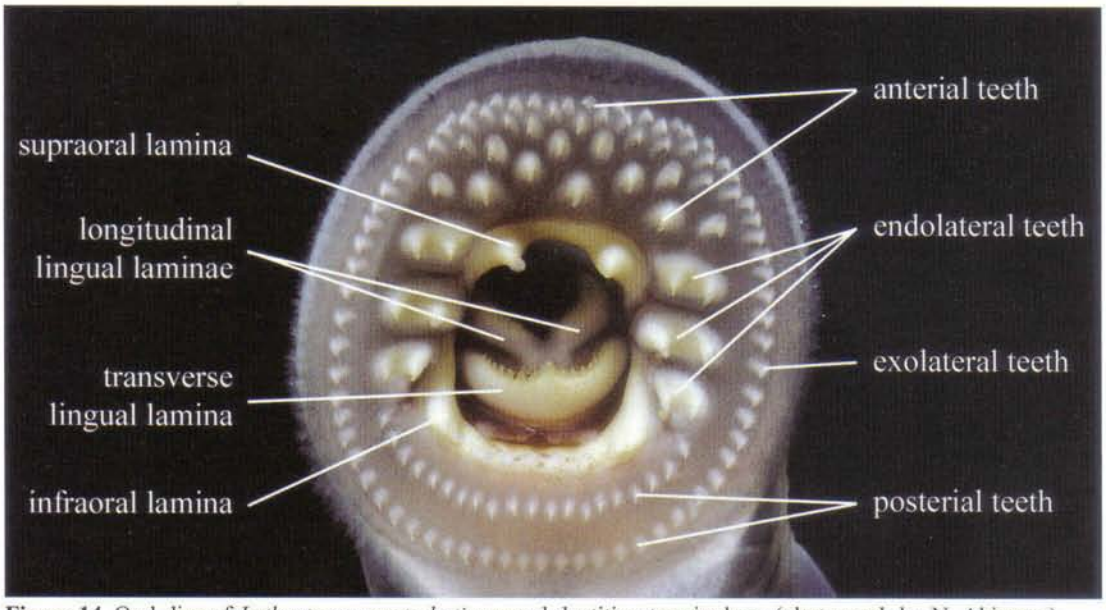

Figure 14 Oral disc of *Lethenteron camtschaticum* and dentition terminology (photograph by N. Akiyama).

Key to genera of Petromyzontidae in Europe

1a – Supraoral lamina narrow, with a single tooth (Fig. 15h) or two adjacent teeth (Fig. 15g); anterial, posterial and exolateral teeth numerous, in regular backward-curved radiating rows (Fig. 15g-h). 2

1b – Supraoral lamina transversely elongate, with a single tooth at each end (Fig. 15a-f); if present, anterial, posterial and exolateral teeth not in regular backward-curved radiating rows (Fig. 15a-f). 3

2a – Infraoral lamina with 4–6 large, blunt teeth (Fig. 15h); oral disc width less than body width (Caspian basin). ..... *Caspiomyzon*

2b – Infraoral lamina with 7–8 large, sharp teeth (Fig. 15g); oral disc width greater than body width (Atlantic, North Sea, Baltic, Mediterranean basins). ..... *Petromyzon*

3a – Several rows of exolateral teeth (may be on a single row along margin of disc in *E. stankokaramani*); posterial teeth usually present; middle endolateral tooth bicuspid (Fig. 15a-c). ..... *Eudontomyzon*

3b – A single row of exolateral teeth along margin of disc; posterial teeth present or absent; middle endolateral tooth bi- or tricuspid (Fig. 15d-f). 4

4a – Middle endolateral tooth tricuspid, if bicuspid then without dark blotch in second dorsal; posterial teeth absent, if present then hardly visible externally (Fig. 15e-f). ..... *Lampetra*

4b – Middle endolateral tooth bicuspid; posterial teeth present at least as a single marginal row behind infraoral lamina; dark blotch in second dorsal (Fig. 15d). ..... *Lethenteron*

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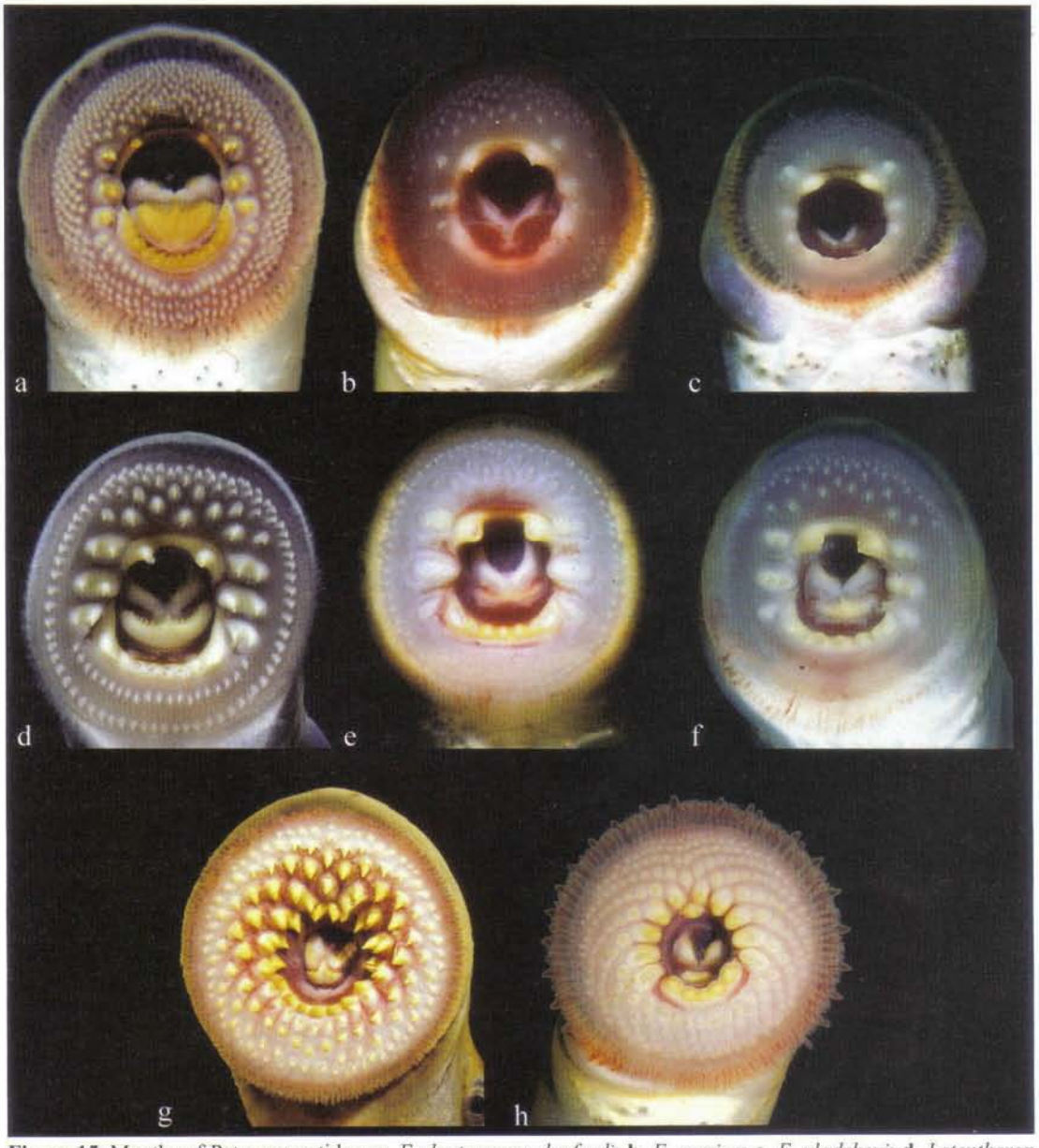

Figure 15 Mouths of Petromyzontidae: **a,** *Eudontomyzon danfordi*; **b,** *E. mariae*; **c,** *E. vladykovi*; **d,** *Letentheron camtschaticum*; **e,** *Lampetra fluviatilis*; **f,** *L. planeri*; **g,** *Petromyzon marinus*; **h,** *Caspiomyzon wagneri* (photographs by Z. Sallai (**a**), N. Akiyama (**d**), A. Hartl (**g**)).

Caspiomyzon wagneri

Common name. Caspian lamprey.

Diagnosis. Single species of genus. Distinguished from other species of family in Europe by: ○ many small teeth in regular backward-curved radiating rows / ○ all teeth low, blunt, button-shaped / ○ supraoral lamina short, with one, rarely two closely connected teeth / ● supraoral lamina tooth blunt / ● infraoral lamina with 4–6 large, blunt teeth (Fig. 15h) / ○ oral disc width less than body width / ○ ammocoetes with 53–68 trunk myomeres. Size up to 550 mm TL.

Distribution. Caspian Sea and tributaries in Europe (Ural, Volga, Terek, Kuma) and Asia. Migrates to uppermost tributaries in Volga.

Habitat. Adults live in sea and spawn in reaches of rivers and streams with strong current. Ammocoetes live in detritus-rich sands or clay sediments.

Biology. Anadromous. Spawns in couples in March – July (River Sakmara, Ural drainage), when temperatures reach 15–23°C. Ammocoete stage lasts 2–4 years in freshwater. Feeds on de-

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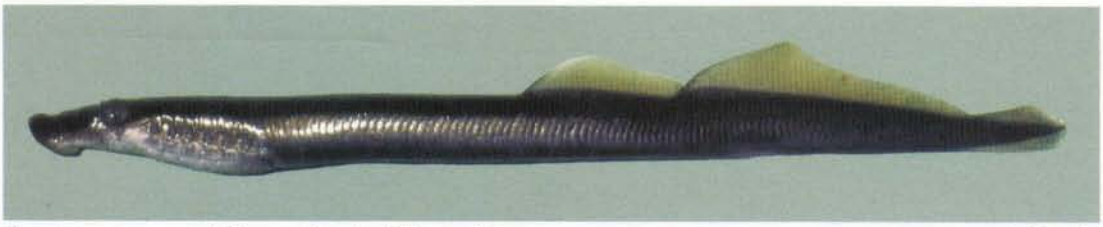
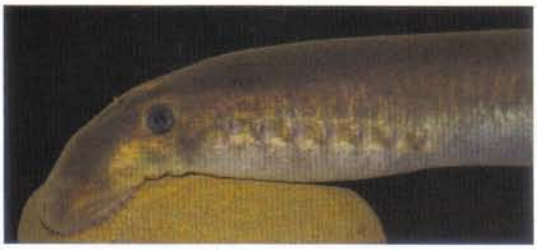


Caspiomyzon wagneri; Samur, Russia; 247 mm TL. A. Naseka



Caspiomyzon wagneri; Tajan, Iran; ~400 mm TL.

tritus and micro-organisms. After metamorphosis, juveniles migrate to the sea. In lower Volga, the occurrence of small (about 190 mm TL) and large (370–550 mm TL) mature adults implies that adults may feed one or two summers before breeding. Feeds on invertebrates and dead fish. Feeding behaviour unknown. Adults start to migrate to rivers in autumn and winter, usually in October – February. Spawning migration is not interrupted by ice flow in Volga. Because of their fat and their abundance, dried *C. wagneri* were earlier used as candles.

Conservation status. NT. In Volga, a sharp decline during 20th century. Rare with only few remaining spawning sites in rivers draining from eastern Caucasus, where it might have stabilised at a low level. Common in most rivers in Iran. Might even be less threatened, but there is no information from River Ural, where it was formerly abundant, since the 1960s. There are indications that it has formed large landlocked populations in reservoirs in the lower Volga.

Further reading. Berg, 1948: 28 (biology); Holčík, 1986: 119 (biology).

Key to species of *Eudontomyzon*

1a – Predatory or parasitic mode of life; breeding adults 140–300 mm TL. 2

1b – Non-predatory mode of life; breeding adults 80–200 mm TL. 3

2a – Non migratory or undertakes only very local migrations (Tisza and Timis systems in Danube drainage). ..... *E. danfordi*

2b – Migratory (Dniestr, Dniepr and Don drainages). ..... *E.* sp. migratory

3a – 53–65 trunk myomeres (Adriatic and Aegean drainages). 4

3b – 61–73 trunk myomeres (Black Sea basin). 5

4a – Caudal rounded. ..... *E. hellenicus*

4b – Caudal spade-like. ..... *E. stankokaramani*

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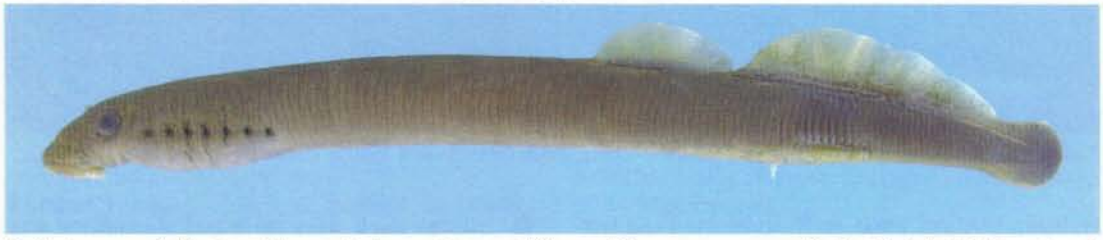
Eudontomyzon danfordi; Tisza, Danube drainage, Hungary; ammocoete, ~100 mm TL. Z. Sallai

Eudontomyzon danfordi; Tisza, Danube drainage, Hungary; adult, ~250 mm TL. Z. Sallai



Eudontomyzon hellenicus; Struma drainage, Greece; 109 mm TL. R. Barbieri & M. Stoumboudi

5a – Caudal hyaline; trunk not mottled in full grown live ammocoetes. ..... *E. vladykovi*

5b – Caudal dark grey to black; trunk mottled in full grown live ammocoetes (mottling lost in preserved specimens). ..... *E. mariae*

Eudontomyzon danfordi

Common name. Carpathian lamprey.

Diagnosis. Distinguished from other species of *Eudontomyzon* in Europe by: ○ predatory mode of life / ○ breeding adults usually 136–300 mm TL / ○ 58–70 trunk myomeres / ○ trunk not mottled in ammocoetes / ○ caudal hyaline. Size up to 300 mm TL.

Distribution. Danube drainage: Tisza and Timis systems (Romania, Slovakia, Ukraine, Hungary).

Habitat. Piedmont and montane zones in clear, well oxygenated brooks. Ammocoetes in detritus-rich sands or clay sediments.

Biology. Predatory, freshwater resident. Ammocoete stage lasts 3½–4½ years. Ammocoetes feed on detritus and insect larvae; they usually metamorphose in July – August. Metamorphosis lasts 1–5 months and feeding starts in the following March. Spawns in spring, usually after one year of predatory life, in April – June in uppermost reaches of brooks. Adults feed on live and dead fish; they usually kill their prey and feed on body tissues or swallow the whole fish.

Conservation status. LC. Suspected slow decline with recent and on-going economic development in eastern Europe.

Further reading. Renaud & Holčík, in Holčík, 1986: 146 (biology).

Eudontomyzon hellenicus

Common name. Greek brook lamprey.

Diagnosis. Distinguished from other species of *Eudontomyzon* in Europe by: ● caudal rounded / ○ non-predatory mode of life / ○ 53–62 trunk myomeres / ○ caudal grey to black. Size up to 152 mm TL.

Distribution. Greece: known from three creeks in Struma drainage.

Eudontomyzon danfordi

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Eudontomyzon mariae; Odra drainage, Poland; ammocoete, ~120 mm TL.

Eudontomyzon mariae; Odra drainage, Poland; adults, male (above) and female (below), ~100 mm TL.

Habitat. Shallow, clear, well oxygenated and fast-flowing brooks with gravel bottom. Ammocoetes live in detritus-rich sands or clay sediments.
Biology. Non-predatory, freshwater resident. Metamorphoses in December. Spawns in December – May.
Conservation status. CR B1ab(i,ii,iii,iv,v)+2ab(i,ii,iii,iv,v). Three known localities; decline in habitat quality.
Remarks. The population from Louros drainage (eastern Greece) either belongs to *E. stankokaramani* or represent a distinct, unnamed species. It is distinguished from *E. hellenicus* by a longer tail (length 29–33 % TL, vs. 26–30) and spade-like (vs. rounded) caudal. It reaches 190 mm TL.
Further reading. Vladykov et al., 1982: 2898 (description); Renaud, in Holčík, 1986: 186 (biology).

Eudontomyzon mariae

Common name. Ukrainian brook lamprey.
Diagnosis. Distinguished from other species of *Eudontomyzon* in Europe by: ○ non-predatory mode of life / ○ 62–73 trunk myomeres / ○ trunk mottled in live ammocoetes older than 2½ years / ○ caudal dark grey to black in adults and ammocoetes older than 1½ years / ○ caudal spade-like. Size up to about 200 mm TL.
Distribution. Tributaries of Baltic (Odra, Vistula, Neman drainages), northern Black (Danube to Kuban drainages) and Caspian Seas (River Sura, Volga drainage). In Danube, restricted to tributaries below Iron Gate; a single record from upper Morava system (Czechia).
Habitat. Lowland, piedmont and montane zones in clear, well oxygenated brooks. Ammocoetes in detritus-rich sands or clay sediments.
Biology. Non-predatory, freshwater resident. Ammocoete stage lasts 3½–4½ years. Feeds on detritus and micro-organisms, metamorphoses in September – December, spawns in late April – early May, later at higher elevations, when temperatures reach 11–16°C. Spawning individuals cease their normal daylight avoidance reaction and reproduce on sunny days. Males dig a shallow nest in habitats with moderate current. Spawners form aggregations.
Conservation status. LC. Frequent in Poland and Ukraine; suspected slow decline with recent and

Eudontomyzon hellenicus

Eudontomyzon mariae

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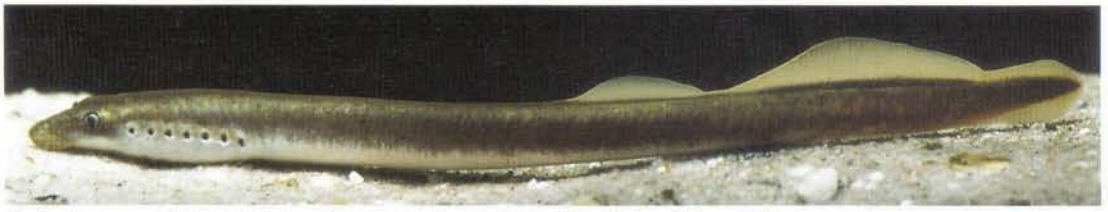
Eudontomyzon vladykovi; Save, Danube drainage, Slovenia; ammocoetes, ~100 mm TL.



Eudontomyzon vladykovi; Save, Danube drainage, Slovenia; adult, ~90 mm TL.

on-going economic development.

Further reading. Holčík & Renaud, in Holčík, 1986: 165 (biology); Kottelat, 1997: 25 (systematics).

Eudontomyzon stankokaramani

Common name. Drin brook lamprey.

Diagnosis. Distinguished from other species of *Eudontomyzon* in Europe by: ○ non-predatory mode of life / ○ 58–65 trunk myomeres / ○ trunk mottled in ammocoetes / ○ caudal grey to black / ○ caudal spade-like / ○ exolateral teeth villiform, very small, weakly developed and frequently absent. Size up to 200 mm TL.

Distribution. Drin drainage, including Lake Ohrid and Lake Skadar basins (Macedonia, Albania, Kosovo, Montenegro).

Habitat. Piedmont and montane zones in clear, well oxygenated brooks. Ammocoete in detritus-rich sands or clay sediments.

Biology. Non-predatory, freshwater resident. Probably similar to *E. mariae*. Metamorphoses in November – April in Drin drainage (requires confirmation).

Conservation status. LC.

Further reading. Karaman, 1974: 2 (description); Kottelat, 1997: 26 (systematics); Holčík & Šorić, 2004 (description).

Eudontomyzon vladykovi

Common name. Danubian brook lamprey.

Diagnosis. Distinguished from other species of *Eudontomyzon* in Europe by: ○ non-predatory mode of life / ○ 61–67 trunk myomeres / ○ trunk not mottled in live ammocoetes / ○ caudal hyaline / ○ caudal spade-like. Size up to 212 mm TL.

Distribution. Upper and middle Danube drainage (Sava and Drava systems and upper Danube north and west of Drava). Locally in Timis and Olt systems (lower Danube drainage). Absent from Tisza and Cerna systems.

Habitat. Clear, well oxygenated brooks in piedmont and montane zones. Ammocoetes in detritus-rich sands or clay sediments.

Biology. Non-predatory, freshwater resident. Ammocoete stage lasts 3½–4½ years. Feeds on detritus and micro-organisms, metamorphoses in July – September, and spawns in March – May, later at higher elevations, when temperatures reach 7–10°C. Spawning individuals cease their normal daylight avoidance reaction and reproduce on sunny days. Males dig shallow nests in habitats with

Eudontomyzon stankokaramani

Eudontomyzon vladykovi

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Eudontomyzon sp. migratory

moderate current.
Conservation status. LC. Suspected slow decline with recent and on-going economic development.
Further reading. Holčík & Renaud, in Holčík, 1986: 165 (as *E. mariae*, in part; biology).

Eudontomyzon sp. migratory

Common name. Ukrainian migratory lamprey.
Diagnosis. Distinguished from other species of *Eudontomyzon* in Europe by: ○ migratory, predatory or parasitic mode of life. Size up to 280 mm TL.
Distribution. Dniestr, Dniepr and Don drainages (Black Sea basin).
Habitat. Unknown.
Biology. Adults were known to migrate and were the target of specific fisheries in lower part of rivers in autumn and spring (including in lower Dniepr where *E. mariae* is known to be absent). It is not known whether the migration was restricted to freshwater or included a period at sea. Spawned during spring in headwaters, in clear water, over gravel bottom or recently flooded areas.
Conservation status. Extinct. Disappeared around the end of 19th century for unknown reasons.
Remarks. Anadromous predatory lampreys are reported in the literature and are considered to be extinct. In fact, the literature is ambiguous. The record of a migratory lamprey in the Prut system refers to a non-predatory species close to *E. mariae* but there is no evidence that it was anadromous or even long-distance mugratory. Attempts to obtain migratory lampreys in recent years in the Dniestr, Dniepr and Don have been unsuccessful; local fishermen are not aware of its existence.
Further reading. Kottelat et al., 2005: 181 (identity).

Key to species of *Lampetra* in Europe

1a – Predatory mode of life; breeding adults 180–450 mm TL. ..... *L. fluviatilis*
1b – Non-predatory mode of life; breeding adults 80–200 mm TL. 2

2a – Middle endolateral tooth tricuspid; 57–67 trunk myomeres ..... *L. planeri*
2b – Middle endolateral tooth bicuspid; 52–59 trunk myomeres. ..... *L. zanandreai*

Lampetra fluviatilis

Common name. European river lamprey.
Diagnosis. Distinguished from other species of *Lampetra* in Europe by: ● predatory mode of life / ● spawning or upstream migrating adults usually 300–450 mm TL, always larger than 180 mm TL / ● size of metamorphosing individuals 80–130 mm TL / ● juveniles uniform silvery grey in spring / ● full-grown female ammocoetes with 10,000–42,000 oocytes / ● oocytes of juveniles 0.02–0.2 mm in diameter in spring / ● 72–100 oocytes in transverse section in front of first dorsal / ○ middle endolateral tooth tricuspid. Size up to 450 mm TL.
Distribution. Ireland, Great Britain north to Scotland, Atlantic coast of France, North Sea north to Scotland and about Bergen (Norway), North and Baltic Sea basins; Mediterranean along French and western Italian coasts. Occasional records in Adriatic and Ionian Seas and along coasts of Iberian Peninsula. Migrates into rivers of this area. Landlocked populations known from Lakes Ladoga and Onega, upper Volga (Russia), Loch Lomond (Scotland), some lakes in Finland and possibly Lough Neagh (Ireland).
Habitat. Adults live in coastal waters and estuaries and spawn in strong-current habitats of rivers and streams. Ammocoetes burrow in detritus-rich sands or clay sediments.
Biology. Predatory, with anadromous and landlocked populations. Adults migrate into rivers from autumn to spring. Migration is mainly nocturnal and ceases at low temperatures. Spawning season starts when water temperature rises above 9°C, which depends on latitude, starting in late March in France and mid-June in Finland. Spawning in-

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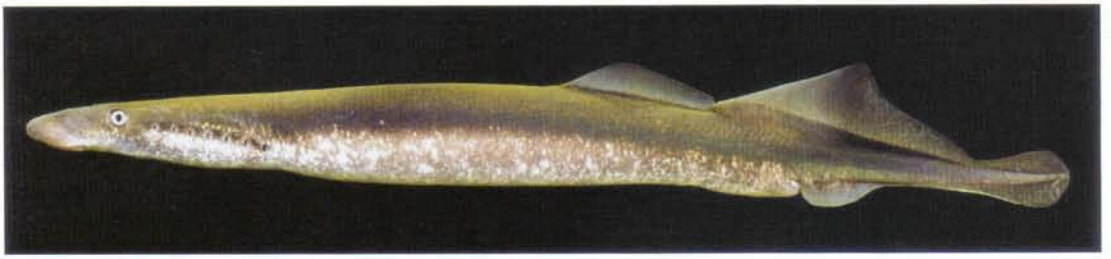


Lampetra fluviatilis; Rhine drainage, Germany; ~400 mm TL. A. Hartl

Lampetra fluviatilis; lower Rhine, Germany; 85 mm TL (same date and locality as *L. planeri* individual below).

Lampetra planeri; lower Rhine, Germany; 130 mm TL.

dividuals cease their normal daylight avoidance reaction and reproduce on sunny days. Males dig shallow nests in habitats with fast current. Spawners form large aggregations. Ammocoete stage lasts 2½–3½ years. Ammocoetes feed on detritus and micro-organisms. After metamorphosis (from late summer to late autumn), most juveniles overwinter in freshwater and migrate to the sea in spring. At sea, adults prey on a wide variety of fish species, mostly Clupeidae and Gadidae. Feeds on body tissues of prey, which is usually killed while its flesh is excavated. Adults feed for 2 (rarely 1) summers before migrating to the spawning grounds. Individuals feeding for only a single summer before breeding are smaller. Landlocked population of Loch Lomond feeds for only one summer, then stops feeding and migrates in autumn to spawning grounds in River Endrick.

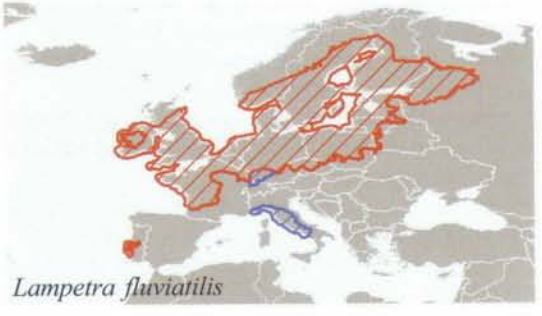
Conservation status. LC. Most likely extirpated from Italian rivers. Still rare in some areas, but populations have markedly recovered following earlier pollution problems in central and western Europe.

Further reading. Hardisty, 1961 (identification); Hardisty et al., 1970 (identification); Potter & Osborne, 1975 (identification); Hardisty, in Holčík, 1986: 248 (biology); Jang & Lucas, 2005 (reproduction).

Lampetra planeri

Common name. European brook lamprey.

Diagnosis. Distinguished from other species of *Lampetra* in Europe by: ❍ non-predatory mode of life / ❍ breeding adults 80–160 mm TL / ❍ size of metamorphosing individuals 120–175 mm TL / ❍ brown with whitish or yellow ventral body in spring / ❍ full-grown female ammocoetes with 5,000–10,000 oocytes / ❍ oocytes 0.5–1 mm in diameter in spring / ❍ 20–35 oocytes in transverse section in front of first dorsal / ❍ 57–67 trunk myomeres / ❍ middle endolateral tooth tricuspid. Size up to 180 mm TL in adults, up to 190 mm TL



Lampetra fluviatilis

Lampetra planeri

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Lampetra zanandreai; Soca drainage, Slovenia; ~80 mm TL. M. Povž

in ammocoetes. A dwarf population maturing at 80–90 mm TL known from Isle of Skye, Inner Hebrides.

Distribution. Great Britain north to Scottish highlands, rivers draining to North Sea north to Scotland and about Stavanger (Norway), Baltic Sea basin, Atlantic as far south as Adour drainage (France, Spain) and isolated populations in Sado, Tagus and Douro drainages (Portugal), Mediterranean basin in France and western Italy (south to about Cilento drainage). Locally in Ireland, upper Volga, upper Danube and some of their tributaries, and Pescara drainage on Adriatic coast of Italy.

Habitat. Found in the lowland, piedmont and montane zone in clear, well oxygenated brooks. Ammocoetes live in detritus-rich sands or clay sediments.

Biology. Non-predatory, freshwater resident. Timing of spawning season depends on latitude when temperature exceeds 9°C, starting in February in Italy and mid-June in Finland. Spawning individuals cease their normal daylight avoidance reaction and reproduce on sunny days. Males dig a shallow nest in habitats with moderate current. Spawners form large aggregations. Dies after spawning. Single individuals may survive until September. Ammocoete stage usually lasts 2½–3½ years (a recent study suggests up to 20 years). Feeds on detritus and micro-organisms, starts metamorphosis in June – July (fully transformed individuals usually found in September), overwinters and spawns following spring. There are indications that *L. planeri* might be an heterogeneous (polyphyletic) assemblage of several lineages evolved independently from different populations of *L. fluviatilis* (see family introduction).

Conservation status. LC. Still rare in some areas, but populations have markedly recovered following earlier pollution problems in central Europe.

Further reading. Hardisty, 1961 (identification); Hardisty et al., 1970 (identification); Potter & Osborne, 1975 (identification); Hardisty, in Holčík, 1986: 279 (biology); Espanhol et al., 2007 (genetics).

Lampetra zanandreai

Lampetra zanandreai

Common name. Adriatic brook lamprey.

Diagnosis. Distinguished from other species of *Lampetra* in Europe by: ○ non-predatory mode of life / ○ breeding adults 80–200 mm TL / ○ middle endolateral teeth bicuspid / ○ 1 row of posterial teeth hardly visible, deeply embedded in disc mucus / ○ 52–59 trunk myomeres. Size up to 260 mm TL.

Distribution. From Alpine slope of Po to Soca drainages (Italy, Switzerland, Slovenia), Esino and Potenza drainage on Adriatic coast of Central Italy. Also in Mirna (Croatia) and Neretva drainage (Bosnia-Herzegovina, Croatia).

Habitat. Piedmont and montane zones in clear, well oxygenated brooks. Ammocoetes live in detritus-rich sands or clay sediments.

Biology. Non-predatory, freshwater resident. Metamorphoses in autumn, overwinters and spawns in spring. Females may metamorphose only a few weeks before spawning, and they have erroneously been considered to be neotenic and spawning as ammocoetes. Timing of spawning season depends on latitude when temperature rises above 9°C, usually in January – March. Spawning individuals cease their normal daylight avoidance reaction and reproduce on sunny days. Males dig a shallow nest in habitats with moderate current. Spawners form large aggregations. Ammocoete stage lasts 3½–4½ years. Feeds on detritus and micro-organisms. In summer, if streams dry, ammocoetes survive by burrowing into the wet, soft substrate.

Conservation status. LC. Suspected slow decline with recent and on-going industrial and agricultural development.

Remarks. Sometimes placed in *Lethenteron*.

Further reading. Bianco, in Holčík, 1986: 237 (biology); Bianco, 1992 (distribution); Holčík & Mrakovčić, 1997 (distribution).

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Lethenteron camtschaticum; Japan. N. Akiyama

Lethenteron reissneri; Amur drainage, Russia. A. Naseka

Lethenteron camtschaticum

Common name. Arctic lamprey.

Diagnosis. Distinguished from *Lethenteron reissneri* by: ● predatory mode of life / ● breeding or upstream migrating adults usually 350–450 mm TL / ● juveniles uniform silvery grey in spring / ● full-grown female ammocoetes with more than 50,000 oocytes. Size up to 625 mm TL.

Distribution. Circumpolar; seas and freshwaters of northern Europe, Asia and North America. In Europe, Arctic, White and Barents Sea basins of Russia and Norway, from Pechora (Russia) to Pasvik (Norwegian-Russian border) drainages.

Habitat. Adults live in coastal and estuarine waters and spawn in strong-current habitats of rivers and streams. Ammocoetes burrow in detritus-rich sands or clay sediments.

Biology. Anadromous, predatory. Adults migrate into rivers in late summer and autumn, until rivers freeze. The migration is mainly nocturnal. Spawning season depends on latitude, when temperatures reach 12–16°C, from April to August. Both sexes dig a shallow nest in habitats with fast current. Spawners form large aggregations. Ammocoete stage lasts 3½ years. Feeds on detritus and microorganisms, metamorphoses in late summer. Most juveniles overwinter in freshwater and migrate to the sea the following spring and early summer. At sea, feeds on a wide variety of fish, mostly Clupeidae and Salmonidae. Feeds on body tissues of the prey, which is usually killed. Adults feed for 1–3 summers before migrating to spawning grounds. Large and small mature individuals might represent different age classes returning from sea to spawn. Landlocked populations are not found in Europe, but are known in Alaska. Individuals of these populations are smaller.

Conservation status. LC. Local pollution and river regulation impacts in Siberia, but no actual risk because of large distribution range.

Remarks. Earlier known as *Lethenteron japonicum*.

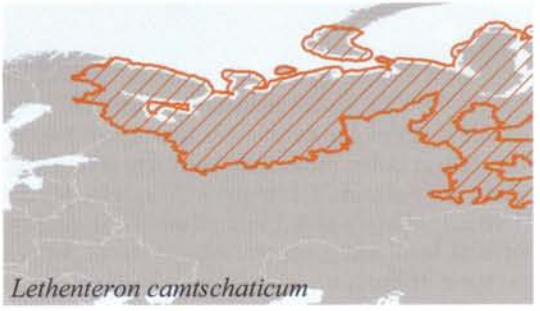
Further reading. Holčík, 1986: 198 (as *L. japonicum*; biology); Yamazaki & Goto, 1998 (genetics).

Lethenteron reissneri

Common name. Siberian lamprey.

Diagnosis. Distinguished from *Lethenteron camtschaticum* by: ● non-predatory mode of life / ● breeding adults 125–260 mm TL / ● in spring, brown with whitish or yellow belly and ventral part of head / ● full-grown female ammocoetes with less than 6,000 oocytes. Size up to 260 mm TL.

Distribution. Drainages of Arctic and Pacific



Lethenteron camtschaticum

Lethenteron reissneri

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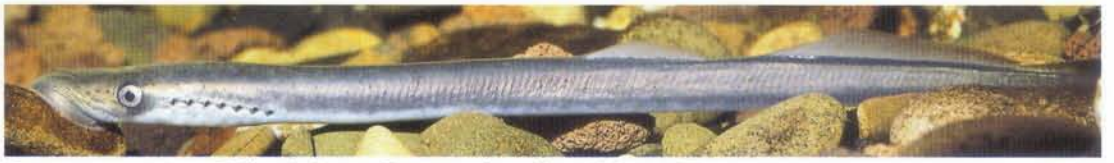
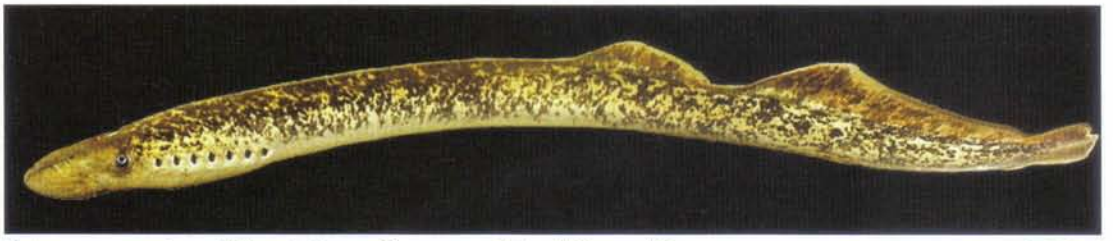
Petromyzon marinus; Rhine drainage, Germany; ammocoete, ~100 mm TL.



Petromyzon marinus; Rhine drainage, Germany; juvenile, ~120 mm TL.



Petromyzon marinus; Rhine drainage, Germany; adult, ~850 mm TL. A. Hartl

Oceans. In Europe in Umba (Kola Peninsula), Severnaya Dvina, Mezen and upper Pechora drainages. In Asia eastward to Anadyr drainage (Bering Sea); Amur drainage; Sakhalin Island; Hokkaido (Japan).

Habitat. All types of rivers and streams, including brackish waters. Spawns in sand-gravel bottom in shallow water. Ammocoetes live in detritus-rich sands or clay sediments. Enters floodplain meadows during high waters.

Biology. Non-predatory, freshwater resident. Timing of spawning season depend on latitude when temperatures reach 13–15°C, from late March to mid-July or later. Migrates into small brooks to spawn. Males dig a shallow nest in habitats with moderate current. Spawners form large aggregations. Ammocoete stage lasts 2½–3½ years. Feeds on detritus and micro-organisms, metamorphoses in late summer, overwinters and spawns in spring. Ammocoetes remaining in temporal floodplain pools burrow into the bottom and form a protective capsule of slimy secretion and remain immobile until water returns.

Conservation status. LC.

Remarks. Lampreys identified as *L. kessleri* from Arctic basin are *L. reissneri*; part of those from Sakhalin, Japan and rivers of the Sea of Japan also belong to *L. reissneri* and to two unnamed species.

Further reading. Holčík, 1986: 220 (biology; as *L. kessleri*); Kudersky, 1998 (distribution); Yamazaki et al., 2006 (genetics, systematics).

Petromyzon marinus

Common name. Atlantic sea lamprey.

Diagnosis. Single species of genus. Distinguished from other species of family in Europe by: ● adults grey to yellow with dark spots, no spots in juveniles / ○ supraoral lamina short, with two adjacent teeth / ● supraoral lamina teeth sharp / ● infraoral lamina with 7–8 large, sharp teeth (Fig. 15g) / ○ oral disc wider than body / ○ many small teeth on oral disc, in regular backward-curved radiating rows / ○ all teeth sharp / ● 66–75 trunk myomeres / ○ ammocoetes with black pigment on caudal. Size up to 1200 mm TL.

Distribution. Both sides of North Atlantic, north to Iceland and along Norwegian coasts to Barents Sea (River Ura, Kola Peninsula). North Sea, Baltic and western and central Mediterranean basins, very rare in Baltic basin, only known to enter Odra, Vistula (Poland, Germany), Western Dvina (Latvia), Narova and Luga (Russia) drainages. Several landlocked populations in North America; none in Europe.

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Habitat. Adults at sea, off-shore; spawns in strong-current habitats of rivers and streams. Ammocoetes in detritus-rich sands or clay sediments.
Biology. Anadromous, parasitic. Adults migrate into rivers from autumn to winter. Spawns in couples in April – July, mostly in May and early June, when temperature reaches at least 15°C. Spawning individuals cease their normal daylight avoidance reaction and reproduce on sunny days. Males dig a shallow nest in habitats with strong current. Ammocoete stage lasts 5½–7½ years. Feeds on diatoms and detritus, metamorphoses at 130–150 mm TL in late summer and migrates to sea. At sea, adults parasite a wide variety of fish species and even whales and other cetaceans. Usually does not kill its hosts, but feeds on small amounts of blood and body fluid for several days on a single host. Adults feed for about 3 years before migrating to spawning grounds.

In 1921, the landlocked population of Lake Ontario entered the other Great Lakes of North America, 90 years after the opening of the Welland Canal in 1829. In combination with other factors, it caused a sharp decline of many native species and the extinction of three endemic Coregonidae.

Recent molecular studies suggest that the European and North American populations might be different species.
Conservation status. LC. Generally rare, but widespread. Populations in central and western Europe, which had declined because of pollution problems, have been recovering since the 1980s.
Further reading. Potter & Osborne, 1975 (identification); Hardisty, in Holčík, 1986: 94 (biology); Rodríguez-Muñoz et al., 2004 (genetics).

Petromyzon marinus; Rhine drainage, Germany; adult, ~850 mm TL. A. Hartl

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Family Acipenseridae

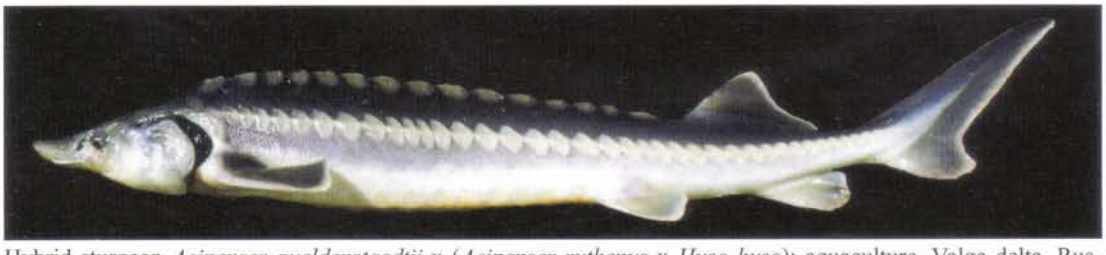
Sturgeons

Sturgeons are a small family restricted to the northern hemisphere. Four genera are recognized. *Scaphirhynchus*, with 3 species from the Mississippi drainage to northern Mexico in North America, and *Pseudoscaphirhynchus*, with at least 3 species, all restricted to the Aral Sea basin, are rheophilous inhabitants of large rivers. *Huso* includes one species in the Sea of Okhotsk, Amur drainage, Sakhalin, Hokkaido and northern China (*H. dauricus*) and one species in Europe (*H. huso*). The largest genus is *Acipenser*, with 9 native species in Europe and 10 in Asia and North America. Most sturgeons are large fishes with 5 rows of hard bony plates, no scales, 4 barbels, projecting snout and inferior mouth forming a protrusible tube. Bony plates or scutes are more prominent in small individuals, being often partly hidden under the skin in adults.

Most sturgeons are anadromous, foraging in marine waters or in freshened parts of seas and undertaking long spawning migrations to large rivers. Upstream migration generally starts in late summer and is less marked when temperatures fall below a threshold. Many individuals overwinter in freshwater. The main peak of upstream migration usually occurs in early spring. The fish returning to rivers in late summer often move and spawn further upstream than individuals that migrate in spring. All species spawn in freshwaters in spring and summer. Spawning generally takes place in fast-flowing water, on gravel bottom. Females return to foraging areas immediately after spawning, while males often remain for many weeks in the spawning grounds, waiting for other females. Females of most species do not spawn every year. Eggs and larvae are very sensitive to low oxygen concentrations. The juveniles of anadromous species usually migrate to the sea during their first summer.

Generally, all native European sturgeons are able to complete their life-cycles in pure freshwater. Five of eight species are reported to include non-anadromous populations or at least some individuals, which remain in riverine habitats. Landlocked stocks of *A. oxyrinchus*, foraging in large lakes and reproducing in their tributaries, were formerly known in Lakes Ladoga and Onega. Non-anadromous, riverine individuals or populations were known in *A. nudiventris*, *A. gueldenstaedtii* and A. *naccarii*; only *A. naccarii* still has a surviving riverine population, all others are now extirpated. Semi-anadromous stocks of *A. ruthenus* were known from lower Volga and are now extirpated; only non-anadromous stocks survive.

Among European fishes, sturgeons are the family most strongly impacted by human activities such as damming and overfishing. *Acipenser ruthenus* is the only species more or less able to resist human impacts. The Atlantic *A. sturio* is now restricted to the Garonne River (France) and its extinction in the wild likely in a few years away. The same is true for the Black Sea *A. colchicus*, whose last known spawning sites are in Georgia; perhaps it earlier spawned in the Çoruh in northeastern Turkey but this river is now blocked by a series of dams. The Baltic population of *A. oxyrinchus* is very likely extirpated. All anadromous sturgeons are now very rare in the Black Sea ba-



Hybrid sturgeon *Acipenser gueldenstaedtii* x (*Acipenser ruthenus* x *Huso huso*); aquaculture, Volga delta, Russia; ~400 mm TL.

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Scute terminology in Acipenseridae

The body of sturgeons is partly covered by a number of scutes or bony plates. Scutes are more prominent in juveniles, and become embedded and reduced with growth. They are most deeply embedded and reduced in adult *Huso huso*. Scutes are organised into 5 longitudinal rows (Fig. 16), one row along the dorsal midline, between the head and the dorsal-fin origin (*dorsal scutes*); one midlateral row on each side, from head to caudal fin (*lateral scutes*); and one row on each side between the pectoral-fin base and the anal-fin origin (*ventral scutes*).

Rhombic or star-shaped bony *denticles* may be present at least between dorsal and lateral scute rows; some denticles are enlarged to form *plates*, especially in posterior part of body. These denticles are very prominent in juveniles of *A. stellatus*, *A. gueldenstaedtii*, *A. colchicus* and *A. persicus* but become relatively smaller and often deeply embedded in adults. In other species, denticles often are absent or very small. In *A. sturio*, denticles are more prominent, larger in size, large and clearly visible in adults. All scutes and denticles may be absent in individual of all species.

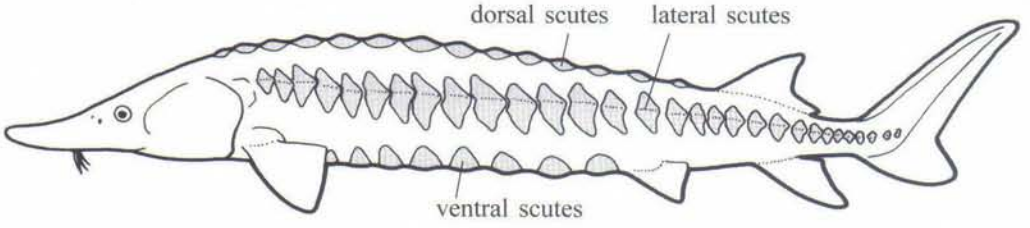

Figure 16 Scute row terminology in Acipenseridae.

sin, following impoundment of almost all spawning rivers. Almost all individuals found today descend from stocked juveniles produced in sturgeon farms. The last Black Sea tributaries still witnessing natural migrating populations are the Danube and the Rioni (Georgia). The Rioni seems to be a key river, inhabited by the last population of *A. nudiventris* in the Black Sea basin and most of the remaining *A. colchicus* (less than 50 captured every year). Even so, these species are still overfished in the Rioni and Danube. The Caspian populations are under massive pressure due to overfishing and the loss of spawning sites. Only the River Ural still presents suitable spawning sites for all species. Overfishing at sea for meat and in rivers for caviar will very soon result in the extinction of many sturgeon species.

Species of sturgeons are very similar in general appearance and characters and are difficult to identify. Because populations of all species except *A. ruthenus* largely depend on stocking of juveniles from fish farms, identification becomes even more problematic. In addition, most sturgeon farms also produce different hybrids. The most frequent is a hybrid between *H. huso* and *A. ruthenus* (called 'bester'), which escapes or is stocked throughout Europe. Further, exotics such as *A. baerii* and different American species are widely produced and stocked. Fish farms in the Black and Caspian Seas usually use wild caught genitors. *A. colchicus* and *A. persicus* outside their main distribution range are often confused with *A. gueldenstaedtii* by sturgeon farmers and mixed with this species. As non-native sturgeons are now widely recorded, especially in central and western Europe, geographic location is no longer useful in the identification of species.

Further reading. Holčík, 1989 (biology, systematics); Birstein et al., 1997 (biology, conservation); Elvira, 2000 (conservation); Pikitch et al., 2005 (conservation, fisheries).

Key to genera and species of Acipenseridae in Europe

1a – Gill membranes joined broadly to each other and free from isthmus (Fig. 17a); very large, crescent-shaped mouth.
..... *Huso huso*

1b – Gill membranes attached to isthmus and not joined to each other (Fig. 17b–c); mouth comparatively small and straight.
..... 2 (*Acipenser*)

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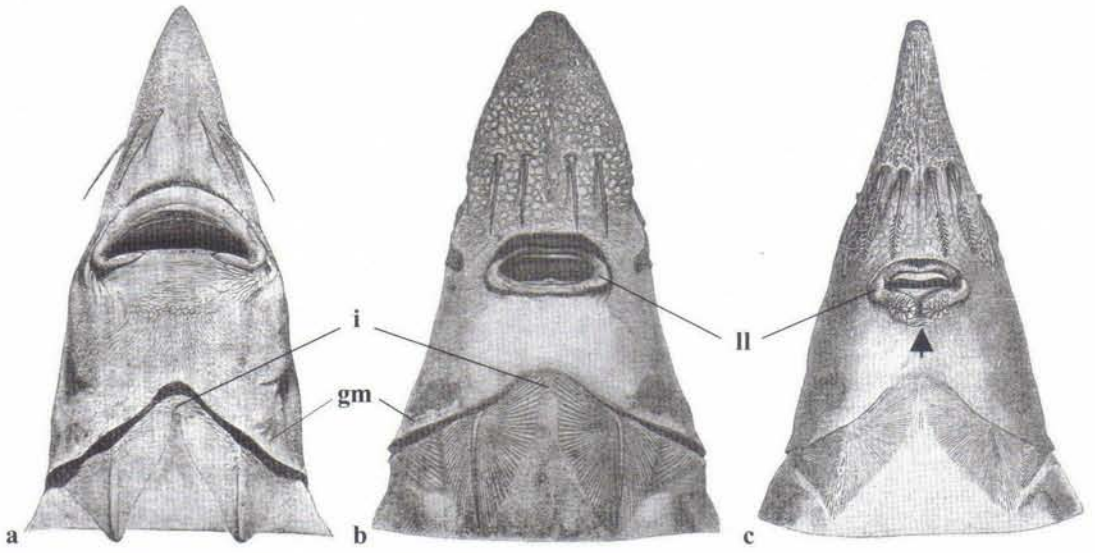

Figure 17 Ventral view of head of: **a,** *Huso dauricus* (an East Asian species); **b,** *Acipenser nudiventris*; **c,** *A. ruthenus*. **gm,** gill membrane; **i**, isthmus; **ll,** lower lip. Arrow points to interrupted lower lip (figures from Berg, 1911).

2a – Lower lip continuous, not interrupted in middle (Fig. 17b); first dorsal scute larger than following ones, fused with head, forming an obtuse angle with head profile; barbels fimbriate. ..... *A. nudiventris*

2b – Lower lip interrupted in middle (Fig. 17c); first dorsal scute not larger than following ones; barbels fimbriate or not. 3

3a – Barbels fimbriate (Fig. 17c); 56–71 lateral scutes. ..... *A. ruthenus*

3b – Barbels not fimbriate; 23–62 lateral scutes. 4

4a – 20–49 fan-shaped gill rakers terminated by several tubercles (Fig. 18); 32–62 lateral scutes. ..... *A. baerii*

4b – 15–35 rod-shaped gill rakers; 23–50 lateral scutes. 5

Figure 18 Fan-shaped gill rakers of *Acipenser baerii*.

5a – 30–35 gill rakers; outer barbels longer than inner ones. ..... *A. naccarii*

5b – 15–31 gill rakers; all barbels of same length. 6

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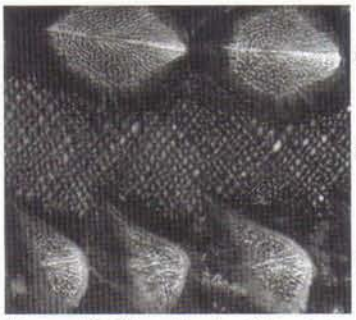

Figure 19 Rhombic denticles between dorsal and lateral scutes in *Acipenser sturio* and *A. oxyrinchus*.

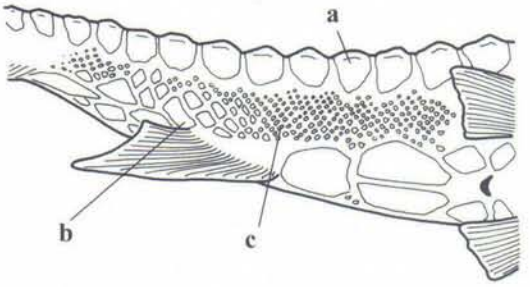

Figure 20 Scutes (**a**), plates (**b**) and denticles (**c**) in anal base area of *Acipenser sturio* and *A. oxyrinchus* (after Artyukhin & Vecsei, 1999).

6a – Rhombic or elongated denticles between dorsal and lateral scutes (Fig. 19); a series of plates along posterior part of anal base (Fig. 20); 2–4 plates along lower edge of caudal peduncle. 7

6b – Star-shaped or roundish denticles between dorsal and lateral scutes; no plates along posterior part of anal base; 0–1 plate along lower edge of caudal peduncle. 8

7a – Dorsal scutes with radiating rows of tubercles (Fig. 21a); no fontanelle between frontal and parietal bones. ..... *A. sturio*

7b – Dorsal scutes with radiating rows of alveoli (Fig. 21b); fontanelle present between frontal and parietal bones (Fig. 22). ..... *A. oxyrinchus*

8a – Base of barbels closer to mouth than to tip of snout; snout very long (59–65 % HL), narrow, depressed. ..... *A. stellatus*

8b – Base of barbels closer to tip of snout than to mouth; snout short (22–36 % HL) and blunt. 9

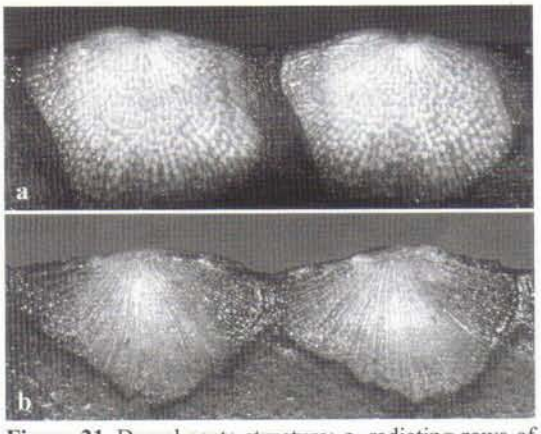

Figure 21 Dorsal scute structure: **a,** radiating rows of tubercles in *Acipenser sturio*; **b,** radiating rows of alveoli in *A. oxyrinchus*.

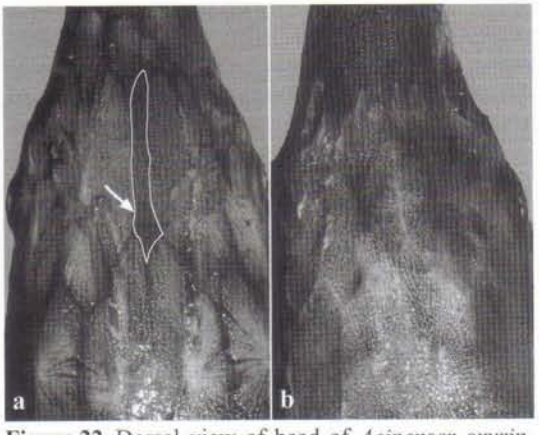

Figure 22 Dorsal view of head of *Acipenser oxyrinchus* (**a**) with fontanelle (outlined, arrow) between frontal and parietal bones, and *A. sturio* (**b**) without fontanelle.

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9a – Dorsal profiles of head and body forming an obtuse angle; belly yellowish; dorsum golden brown; snout short, blunt and somewhat rounded, its depth at eye about equal to or smaller than its length.
..... *A. gueldenstaedtii*

9b – Dorsal profiles of head and body continuous; belly white; dorsum greyish-blue to black; snout elongate and curved downward, its depth at eye smaller than its length.
..... 10

10a – Head width at mouth about 37 % HL; head and body below lateral scutes lighter than on back; no longitudinal bony denticles or small plates below lateral scutes.
..... *A. persicus*

10b – Head width at mouth about 30 % HL; head and body below lateral scutes not lighter than on back; longitudinal bony denticles or small plates present below lateral scutes.
..... *A. colchicus*

Acipenser baerii

Common name. Siberian sturgeon.

Diagnosis. Distinguished from other species of *Acipenser* by: ● 20–49 fan-shaped gill rakers terminated by several tubercles (Fig. 18) / ○ lower lip interrupted in middle / ○ 10–20 dorsal scutes / ○ 32–62 lateral scutes / ○ 7–16 ventral scutes / ○ barbels not fimbriate / ○ tetraploid. Size usually up to 2000 mm TL and 210 kg.

Distribution. Siberia (from Ob to Kolyma drainages, Lake Baikal). Aquaculture has resulted in intentional and accidental releases throughout Europe. No known reproducing population in Europe.

Habitat. Deep parts of large rivers, with moderate to swift current. Spawns in main river channel over stone-gravel or gravel-sand bottom, in strong currents.

Biology. Non-anadromous migratory. Males reproduce for the first time at 11–24 years, females at 20–28 (9–10 and 11–12, respectively, in Lena drainage). Females reproduce every 3–5 and males every 2–3 years in May – June, at 9–18°C. In Siberian rivers, there are both a sedentary and a migratory 'forms'. Migratory individuals feed in estuaries and migrate upriver to spawn. Prior to the construction of dams on River Ob, they migrated about 3000 km upstream. Spawning migration starts in autumn. Sedentary individuals inhabit middle and upper stretches of rivers and do not undertake long migrations. Feeds on a variety of benthic organisms such as crustaceans and chironomid larvae.

Conservation status. Alien. VU A2d in native range.

Further reading. Sokolov & Vasiliev, in Holčík, 1989: 263 (biology).

Acipenser colchicus

Common name. Caucasian sturgeon.

Diagnosis. Distinguished from other species of *Acipenser* in Black Sea basin by: ○ presence of longitudinal, star-shaped bony denticles below lateral scutes / ○ head and belly not lighter than dorsum / ○ base of barbels closer to tip of snout than to mouth / ○ barbels not fimbriate / ○ lower lip interrupted in middle / ○ snout elongate, massive and curved downward / ○ no plate along posterior part of anal base / ○ 0–1 plate along lower edge of caudal peduncle / ○ 16–31 gill rakers / ○ 7–19 dorsal scutes / ○ 24–35 lateral scutes. Size up to about 2000 mm TL.

Distribution. Southeastern Black Sea basin, Rioni drainage and Georgian and Turkish coast; lower Danube.

Habitat. At sea, coastal and estuarine zones. Spawning in strong-current habitats in main stream of large and deep rivers on stone or gravel

Acipenser baerii; aquaculture, Russia; ~700 mm TL. A. Hartl

watermanⓒ

Acipenser colchicus; lower Rioni, Georgia; ~250 mm TL. J. Gessner

bottom. Juveniles in riverine habitats during first summer.

Biology. Anadromous. Males reproduce for the first time at 8–12 years, females at 13–15. Known to migrate and spawn in July at 17–23°C. Juveniles migrate to sea during first summer and remain there until maturity. At sea, feeds on a wide variety of benthic molluscs, crustaceans and small fish.

Conservation status. CR A2d; B2ab(ii,iii,v); C1*. Almost extinct. Now only occasionally recorded from Georgian and Turkish coasts. Presence generally ignored, individuals often being confused with *A. gueldenstaedtii*. One of the most threatened fish species in Europe, but there is no known attempt to protect it. Latest recorded spawning in 2000.

Further reading. Vlasenko et al., in Holčík, 1989: 345 (as *P. persicus* in part; biology).

Acipenser gueldenstaedtii

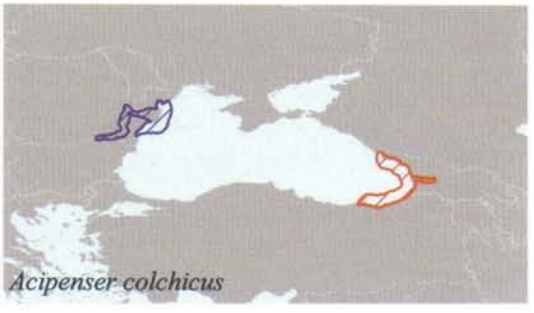
Common name. Russian sturgeon.

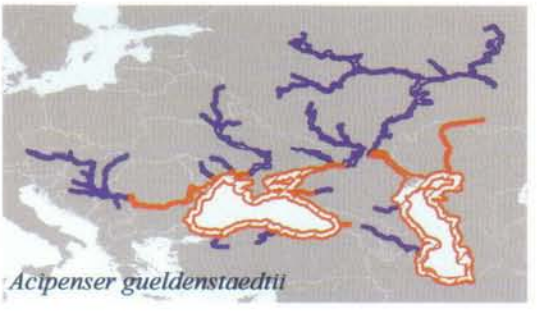
Diagnosis. Distinguished from other species of *Acipenser* in Europe by: ❍ base of barbels closer to tip of snout than to mouth / ❍ barbels not fimbriate / ❍ lower lip interrupted in middle / ❍ 15–31 gill rakers / ❍ 8–19 dorsal scutes / ❍ 24–50 lateral scutes / ❍ 6–13 ventral scutes / ❍ snout short (22–36 % HL) and blunt / ❍ head length 17–19 % TL / ❍ many star-shaped bony denticles of various sizes between dorsal and lateral scutes / ❍ dorsum golden brown, belly yellowish white / ❍ dorsal profiles of head and body forming an obtuse angle / ❍ no plates along posterior part of anal base / ❍ 0–1 plate along lower edge of caudal peduncle / ❍ tetraploid. Size up to 2360 mm TL and 115 kg. Records of size up to 4000 mm TL are not supported by evidences. Subfossil specimens about 3000 mm TL.

Distribution. Caspian, Black and Azov Sea basins. Aquaculture has resulted in intentional and accidental introductions throughout Europe.

Habitat. At sea, shallow coastal and estuarine zones. In freshwaters, in deep parts of large rivers with moderate to swift current. Spawns in strong current (1–1.5 m/s) in large and deep rivers on stone or gravel bottom.

Biology. Anadromous and freshwater populations





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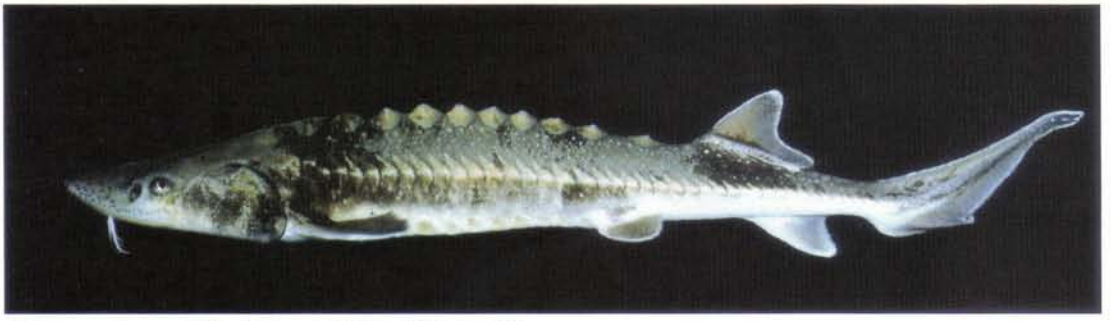
Acipenser gueldenstaedtii; Volga, Russia; ~900 mm TL. A. Hartl



Acipenser naccarii; Po drainage, Italy; ~700 mm TL.

are known. A complicated pattern of spawning migrations includes spring and autumn runs. Individuals migrating in spring enter freshwater just before spawning; they tend to spawn in lower reaches of rivers (320–650 km in unregulated Ural). Individuals migrating in autumn overwinter in rivers and spawn the following spring further upstream (900–1200 km in Ural). Males reproduce for the first time at 8–13 years, females at 10–16. Females reproduce every 4–6 and males every 2–3 years in April – June when the temperature rises above 10°C. Larvae drift on currents; juveniles then move towards shallower habitats, before migrating to the sea during their first summer. They remain at sea until maturity. Feeds on a wide variety of benthic molluscs, crustaceans and small fish.

Conservation status. CR A2d + 3d*. Very rare in Black Sea basin. Almost all spawning sites lost because of dam construction. Last natural population still migrates to Danube, where sturgeons are heavily overfished. Caspian populations under massive pressure from overfishing and loss of spawning habitats. Almost all migrating spawners poached below Volgograd dam. Overfishing at sea for meat will soon result in extinction of natural populations. In the immediate future, survival can only depend on stocking.

Further reading. Vlasenko et al., in Holčík, 1989: 294 (biology).

Acipenser naccarii

Common name. Adriatic sturgeon.

Diagnosis. Distinguished from other species of *Acipenser* in Europe by: O base of barbels closer to tip of snout than to mouth / O barbels not fimbriate / O outer barbels longer than inner ones / O lower lip interrupted in middle / O 30–35 gill rakers / O snout short (37–40 % HL) and blunt / O head length 20–22 % TL / O 10–14 dorsal scutes / O 32–42 lateral scutes / O 8–11 ventral scutes / O lateral scutes twice as high as wide / O many small, granuliform or star-shaped bony denticles between dorsal and lateral scutes / O tetraploid. Size up to 2000 mm TL and 25 kg, usually much smaller.

Distribution. Adriatic Sea and its tributaries between Po (Italy) and Buna (Albania) drainages. Recorded from Corfu. Present in lowermost part of Adriatic rivers from Soca to Drin. Records from Tyrrhenian slope of Italy, Spain and France are erroneous.

Habitat. At sea, close to shore and estuaries, not entering pure marine waters. In freshwater, large, deep rivers.

Biology. Anadromous, forming landlocked pop-

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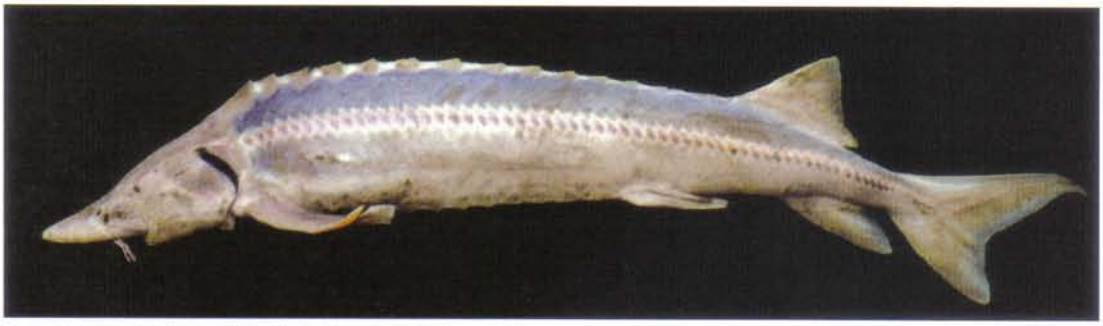


Acipenser nudiventris; Rioni, Georgia; ~1200 mm TL. J. Gessner

ulations above dams. Males reproduce for the first time at 6–8 years, females at 8–12. Females reproduce every 2–4 and males every 1–2 years in spring. Feeds on benthic invertebrates (mainly gammarids, chironomids, oligochetes) and fish. Little information available on biology.

Conservation status. CR A2abc; B2ab(i,ii,iii, iv,v)*. Now very rare in the wild. Nearly all individuals originate from stocking programs in Italy. Apparently a single surviving naturally-spawning population at confluence of Ticino and Po. Only occasional records from Adriatic Sea and coastal rivers. Spawning populations reportedly survived in Albania, but have possibly been extirpated in recent years.

Further reading. Tortonese, in Holčík, 1989: 284 (biology); Gandolfi et al., 1991: 83 (biology); Doukakis et al., 2000 and Rincón, 2000 (on alleged records in Spain).

Acipenser nudiventris

Common name. Ship sturgeon.

Diagnosis. Distinguished from other species of family in Europe by: ● lower lip continuous, not interrupted in middle (Fig. 17b) / ● first dorsal scute larger than following ones, fused with head, forming an obtuse angle with head profile / ○ barbels fimbriate / ○ 24–45 gill rakers / ○ 11–17 dorsal scutes / ○ 49–74 lateral scutes / ○ diploid. Size up to 2200 mm TL.

Distribution. Black, Azov, Caspian and Aral Seas, ascending some rivers (Danube up to Bratislava, Volga up to Kazan, Ural up to Chkalov), unknown or very rare in others. Introduced in Lake Balkhash (Kazakhstan) from River Syr-Darya (Aral basin) in the 1960s.

Habitat. At sea, close to shores and estuaries. In freshwaters, deep stretches of large rivers. Juveniles in shallow riverine habitats. Spawns in strong-current habitats in main course of large and deep rivers on stone or gravel bottom.

Biology. Anadromous, with some non-migratory freshwater populations. Males reproduce for the first time at 6–15 years, females at 12–22. In most drainages, there are two migration runs, in spring and autumn. Individuals migrating in autumn remain in the river until the following spring to spawn. Females reproduce every 2–3 and males every 1–2 years in March – May and at temperatures above 10°C. Most juveniles move to sea in their first summer and remain there until maturity. Some individuals remain in freshwater for a longer period. Feeds on a wide variety of benthic fishes, molluscs and crustaceans.

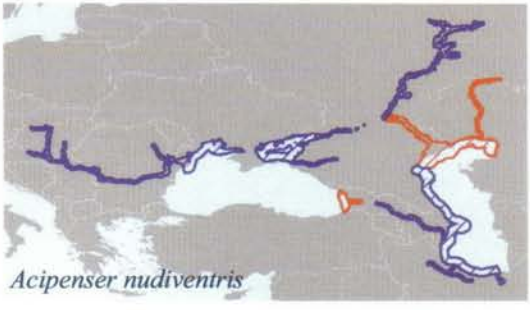
Conservation status. CR A2d + 3d*. On the verge of extinction in its natural range. Extirpated in Aral basin. Nearly extirpated in Black Sea basin. Only occasional records from Danube and lower Volga. Only a very small population remaining in Rivers Ural (Russia, Kazakhstan) and Rioni (Georgia). No natural spawning in Iran. Established in Lake Balkhash where it forms a large population. Caspian *A. stellatus* introduced to Aral basin were infected by the parasitic nematode *Nitzschia sturionis*, which caused the collapse of the Aral population of *A. nudiventris*.

Further reading. Sokolov & Vasiliev, in Holčík, 1989: 206 (biology).

Acipenser oxyrinchus

Common name. American Atlantic sturgeon.

Diagnosis. Distinguished from other species of *Acipenser* in Europe by: ○ many rhombic denticles between dorsal and lateral scutes (Fig. 19) / ○ a series of plates along posterior part of anal base (Fig. 20) / ○ 2–4 plates along lower edge of



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Acipenser oxyrinchus; Baltic Sea, Estonia; ~2600 mm TL. T. Paaver

Acipenser persicus; Caspian Sea, Iran; ~800 mm TL. A. Abdoli

caudal peduncle / ○ dorsal scutes with radiating rows of alveoli (Fig. 21b) / ○ fontanelle present between frontal and parietal bones (Fig. 22a), closed in individuals larger than 900 mm TL / ○ first dorsal scute fused with head / ○ 24–40 lateral scutes / ○ base of barbels midway between mouth and tip of snout or closer to mouth / ○ barbels not fimbriate / ○ 15–29 gill rakers / ○ lower lip interrupted in middle / ○ diploid. Largest documented size 4300 mm TL, but today rarely exceeds 2000 mm TL.

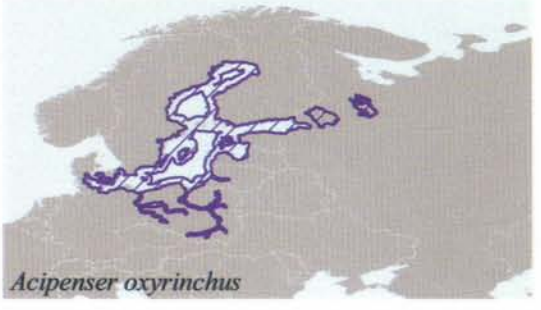
Distribution. In Europe: Baltic Sea. Landlocked populations in Lakes Ladoga and Onega (Russia), both now extirpated. Occasionally recorded from Great Britain and North Sea (Elbe drainage). In North America: Atlantic coast from Labrador to Mississippi delta.

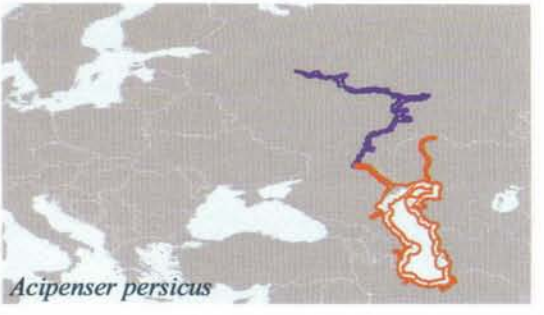
Habitat. At sea, coastal and estuarine zones on soft bottom. In freshwaters, estuaries and large rivers. Forage mostly in brackish waters. Long migrations along coasts.

Biology. Anadromous and landlocked populations. Ladoga landlocked population spawned in June – July in River Volkhov. Females spawn for the first time at 7–19 years in South Carolina and at 27–28 in River St. Lawrence. Females do not spawn every year. Spawns in March – August when temperature rises above 13°C, later in northern populations. Spawning migrations start in autumn and peak in February – March. Individuals migrating in autumn overwinter in river and spawn in spring. Spawns in strong-current habitats in large and deep rivers, on stone or gravel bottom. Spent individuals return directly to sea. Juveniles migrate to estuaries during first summer, but some leave freshwater habitat after 2–4 years. At sea, feeds on a variety of molluscs, crustaceans and small fish.

Conservation status. NT globally, but extirpated in Europe due to massive overfishing, damming, river regulation and pollution. Decline began in 19th century, perhaps even earlier. Last known Baltic individual was an adult female 2900 mm TL and 135 kg caught in 1996 along the Estonian coast. Last adult recorded along the coast of Wales was 2760 mm TL caught in 2005. Lower risk in North America.

Remarks. Archaeological records and genetic markers suggest that this species colonised the Baltic Sea basin about 1,800 years ago from North America and replaced *A. sturio* about 800 years ago in Baltic Sea.





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Acipenser ruthenus; Danube, Hungary; ~400 mm TL. A. Hartl

Further reading. Holčík et al., in Holčík, 1989: 367 (biology; as *A. sturio*, in part), 2000: 139 (conservation); Jenkins & Burkhead, 1993: 187 (biology); Ludwig et al., 2002 (genetics, history); Boschung & Mayden, 2003: 105 (biology).

Acipenser persicus

Common name. Persian sturgeon.

Diagnosis. Distinguished from oter species of *Acipenser* in Caspian basin by: ❍ small, longitudinal bony denticles only between dorsal and lateral scutes / ❍ dorsum greyish-blue, belly white / ❍ base of barbels closer to tip of snout than to mouth / ❍ barbels not fimbriate / ❍ lower lip interrupted in middle / ❍ snout elongate, massive and curved downward / ❍ dorsal profiles of head and body continuous / ❍ no plate along posterior part of anal base / ❍ 0–1 plate along lower edge of caudal peduncle / ❍ 15–31 gill rakers / ❍ 8–14 dorsal scutes / ❍ 23–41 lateral scutes / ❍ 7–13 ventral scutes. Size up to 2280 mm TL and 70 kg.

Distribution. Caspian basin, most abundant in southern part.

Habitat. At sea, coastal and estuarine zones. Spawns in strong-current habitats in main course of large and deep rivers on stone or gravel bottom. Juveniles in riverine habitats during their first summer.

Biology. Anadromous. Males reproduce for the first time at 8–15 years, females at 12–18. Does not spawn every year. Spawns in June – August when temperature rises above 16°C. In southern Caspian basin, spawns in April – September but reproduction is interrupted from June to August when temperature rises above 25°C. Most individuals migrate upriver in April – May, but some may enter rivers at other times of the year. In southern Caspian basin, there is a second run in September – October. Juveniles migrate to the sea during their first summer and remain there until maturity. At sea, feeds on a wide variety of benthic molluscs, crustaceans and small fish.

Conservation status. CR A2acd + 3acd*. European populations almost extirpated. Only occasional records from northern Caspian basin, where no spawning population remains. Most likely no natural reproduction in Iranian waters, but massively stocked from artificial reproduction. Recently, fish from Iranian stocking programs have been observed more frequently in northern Caspian.

Further reading. Vlasenko et al., in Holčík, 1989: 345 (biology).

Acipenser ruthenus

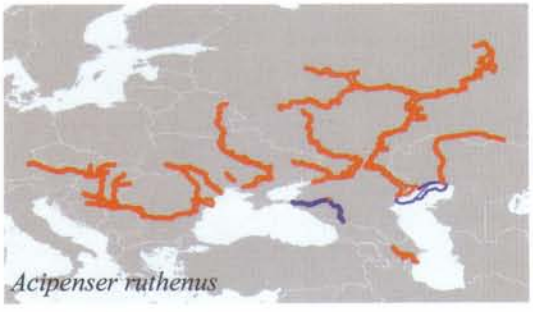
Common name. Sterlet.

Diagnosis. Distinguished from other species of *Acipenser* in Europe by: ❍ 56–71 lateral scutes / ❍ first dorsal scute not fused with head / ❍ barbels fimbriate (Fig. 17c) / ❍ lower lip interrupted in middle / ❍ 11–27 gill rakers / ❍ diploid. Size up to 1250 mm TL and 16 kg.

Distribution. Rivers draining to Black, Azov and Caspian Seas; Siberia from Ob eastward to Yenisei drainages. Introduced in Pechora drainage in 1928–1950 and in Lake Ladoga basin. Aquaculture has resulted in intentional and accidental introductions throughout Europe, without formation of self-sustaining populations.

Habitat. Large rivers, usually in the current and in deep water. When water level rises, moves to flooded areas to feed. Spawns in strong-current habitats on gravel, rarely on gravel-sand bottom or in floodplain sites. Juveniles in shallow riverine habitats during first summer.

Biology. Freshwater; anadromous populations have been extirpated. Males reproduce for the first time at 3–5 years, females at 5–8. Females reproduce every 1–2 years and males every year in April – June when temperature rises above 10°C. Sed-



Acipenser ruthenus

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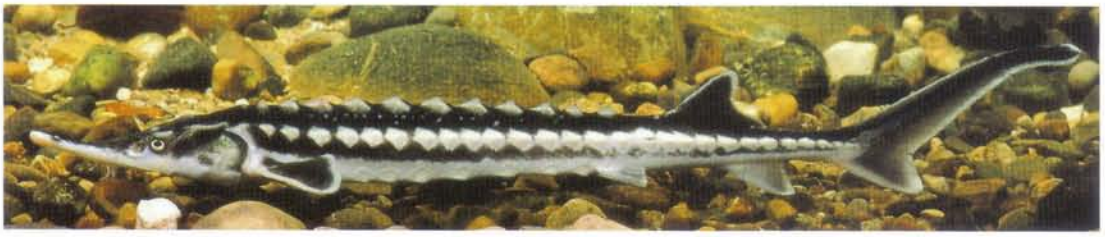


Acipenser stellatus; Volga, Russia; ~600 mm TL. A. Hartl

Acipenser stellatus; Danube, Hungary; ~1200 mm TL. Z. Sallai

entary; undertakes only short spawning migrations (322 km reported from Danube). There was a migratory population with large-growing individuals in Volga until end of 19th century, feeding in the northern Caspian Sea and moving upriver in autumn. Feeds on a wide variety of benthic insect larvae and molluscs.

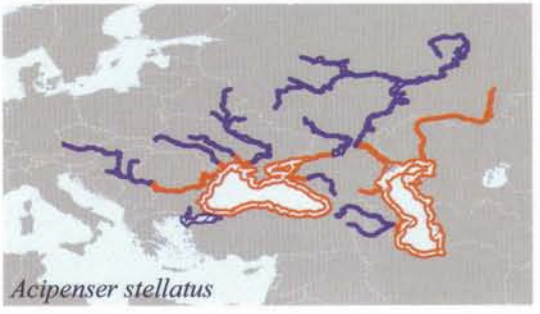
Conservation status. EN A2d*. Massive decline, but local populations surviving in most parts of range. Stocked in large numbers in Danube and perhaps elsewhere. Extirpated in Kuban drainage.

Further reading. Sokolov & Vasiliev, in Holčík, 1989: 226 (biology).

Acipenser stellatus

Common name. Stellate sturgeon.

Diagnosis. Distinguished from other species of *Acipenser* by: ● snout very long (59–65 % HL), narrow, dorsoventrally compressed / ○ star-shaped bony denticles between rows of scutes / ○ 9–16 dorsal scutes / ○ 26–43 lateral scutes / ○ 9–14 ventral scutes / ○ base of barbels closer to mouth than to tip of snout / ○ lower lip interrupted in middle / ○ 24–29 gill rakers / ○ diploid. Size up to 2180 mm TL and 54 kg.



Distribution. Caspian, Black, Asov and Aegean Seas, ascending rivers to spawn. Records from Albania need confirmation. Introduced in Aral Sea.

Habitat. At sea, coastal and estuarine zones, forages on bottom mostly on clayey sand and intensively in middle and upper water layers. Spawns in strong-current habitats in main course of large and deep rivers, on stone or gravel bottom. Also spawns on flooded river banks; if gravel bottom is not available, spawns on sand or sandy clay. Juveniles in shallow riverine habitats during first summer.

Biology. Anadromous. Males reproduce for the first time at 6–12 years, females at 8–14. Females reproduce every 3–4 and males every 2–3 years in April – September. Spawns only under relatively constant hydrological conditions. Fluctuating hydrological conditions lead to high egg mortality. Upriver migrations with two peaks, in spring and in autumn. Migrates at higher temperatures and therefore later than other sturgeons. Males remain at spawning sites no longer than six weeks and females only 10–12 days. Spent individuals migrate directly back to sea. Yolk-sac larvae pelagic for 2–3 days and drift with current. Juveniles migrate to sea during their first summer and remain there until maturity. At sea, feeds on a wide variety of crustaceans, molluscs and benthic as well as pelagic fish.

Conservation status. CR A2d + 3d*. Extirpated from Aegean Sea. In Black Sea basin, last natural population still migrates to Danube, where it is heavily overfished. Only very few spawners remain in rest of Black Sea basin. Large numbers were stocked from Caspian to Azov basins in 1961–1986. Caspian populations under massive pressure from overfishing and loss of spawning

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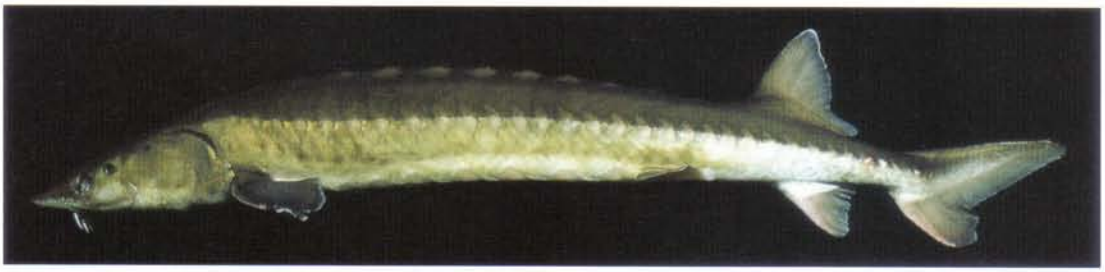

Acipenser sturio; Gironde, France; ~1200 mm TL. M. Roggo

sites. Stocks declining very fast. Almost all migrating spawners poached below Volgograd dam. Overfishing at sea for meat and caviar will soon cause extinction of the natural populations. In the immediate future, survival can only depend on stocking. Caspian *A. stellatus* introduced to Aral basin were infected by the parasitic nematode *Nitzschia sturionis*, which caused the collapse of the Aral population of *A. nudiventris*.

Further reading. Shubina et al., in Holčík, 1989: 395 (biology); Economidis et al., 2000b: 84 (Aegean Sea).

Acipenser sturio

Common name. Atlantic sturgeon.

Diagnosis. Distinguished from other species of *Acipenser* in Europe by: ❍ many rhombic denticles between dorsal and lateral scutes (Fig. 19) / ❍ dorsal scutes with radiating rows of tubercles (Fig. 21a) / ❍ no fontanelle between frontal and parietal bones / ❍ a series of plates along posterior part of anal base (Fig. 20) / ❍ 2–4 plates along lower edge of caudal peduncle / ❍ first dorsal scute fused with head / ❍ 24–40 lateral scutes / ❍ base of barbels midway between mouth and tip of snout or closer to mouth / ❍ barbels not fimbriate / ❍ 15–29 gill rakers / ❍ lower lip interrupted in middle / ❍diploid. Largest documented size 6000 mm TL and 1000 kg, but today rarely exceed 2000 mm TL.

Distribution. North and White Seas, European coasts of Atlantic, northern Mediterranean eastward to Rhodos, western and southern Black Sea. Occasionally recorded from Iceland, Morocco and Algeria. Anadromous, in most large rivers, but not recorded from Danube upriver of delta. Today restricted to Garonne (France) drainage.

Habitat. At sea, coastal and estuarine zones on soft bottom. In freshwaters, estuaries and large river.

Biology. Anadromous. Males reproduce for the first time at 9–13 years, females at 11–18. Females reproduce every second year and males every year in March – August when temperature rises above 20°C, later in northern populations and populations spawning more upriver. Spawning

The fate of the last *Acipenser sturio*

Acipenser sturio is one of the most endangered European fish, strictly protected at national level in most countries, at European level and by a number of international agreements. Protection depends largely of the efficiency and attention of those in charge of enforcing laws. It is interesting to record the fate of the last sturgeons ...

... in the Black Sea: The last known individual of *A. sturio* in the Black Sea basin was caught by fishermen in 1991 in Georgia. It was recognized by scientists who tried to transport it alive to a research aquarium. On the way, they were stopped by a policeman, the fish was 'confiscated' and barbecued.

... in the Mediterranean Sea: The last known individual of *A. sturio* in the Mediterranean Sea basin was caught by fishermen in 1991 in Italy and sold on a local market.

... in Spain: The last known individual of *A. sturio* on the Iberian Atlantic coast was caught by fishermen in 1992 close to the Guadalquivir estuary, close to Doñana National Park and sold to a local restaurant. The chef took the last pictures and the fish was then served to the guests.

... in Germany: The last *A. sturio* caught in the North Sea was reportedly caught dead in 1993 and was landed illegally in Germany. It was sold on the fish market and eaten in the canteen of the Ministry of Interior.

... in Belgium: A juvenile *A. sturio* tagged in the Gironde estuary was caught on 12 February 2007 off the Belgian coast. It was released shortly after catch. Hopefully this animal will once return to the Gironde to reproduce. We hope this will be the fate of the sturgeons in future.

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Huso huso; Volga, Russia; ~1000 mm TL. A. Hartl

migrations peak in spring, with a secondary, weak peak in late summer and autumn. Individuals migrating in late summer overwinter in river and spawn in spring. Spawns in strong-current habitats, in large and deep rivers, on stone to gravel bottom. Spent individuals return directly to sea. Some juveniles migrate to sea during first summer, but most leave freshwater habitat after 2–4 years and remain at sea until maturity. At sea, feeds on a variety of molluscs, worms, crustaceans and small fish. Atlantic populations feed in benthic zone, while Black Sea populations feed in pelagic zone, mostly on anchovies.

Conservation status. CR A2d + 3d; B2ab(ii, iii,v)*, due to massive overfishing, damming, river regulation and pollution. Decline began in 19th century or perhaps even earlier. Last remaining population (in France) still declining. Last natural spawning in 1994. By-catch and unintentional kills (about 200 per year) are still a major problem. Overfishing will soon result in extinction of natural populations.

Remarks. Archaeological remains suggest that *A. sturio* colonised Baltic Sea basin about 3000 years ago from North Sea and vanished from Baltic Sea basin about 800 years ago for unknown reasons; climatic changes about 1000 yeas ago (Little Ice Age) might have had an impact.

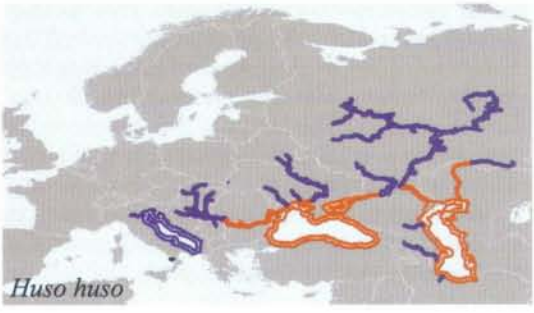
Further reading. Holčík et al., in Holčík, 1989: 367 (biology), 2000: 139 (conservation); Elvira, 2000 (biology); Bacalbasa-Dobrovici & Holčík, 2000: 37 (Black Sea population); Rochard, in Keith & Allardi, 2001: 108 (status in France). Ludwig et al., 2002 (genetics).

Huso huso

Common name. Beluga.

Diagnosis. Distinguished from other species of family by: ● gill membranes joined and free from isthmus (Fig. 17a) / ● mouth very large, cres-

Acipenser sturio



Huso huso

watermanⓒ

Huso huso; Volga, Russia; ~1000 mm TL. A. Hartl

cent-shaped / ♂ 9–17 dorsal scutes / ♂ 37–53 lateral scutes / ♂ 7–14 ventral scutes / ♂ 17–36 gill rakers. Largest documented size 8000 mm TL and 3200 kg, but generally below 5000 mm TL and 1000 kg.

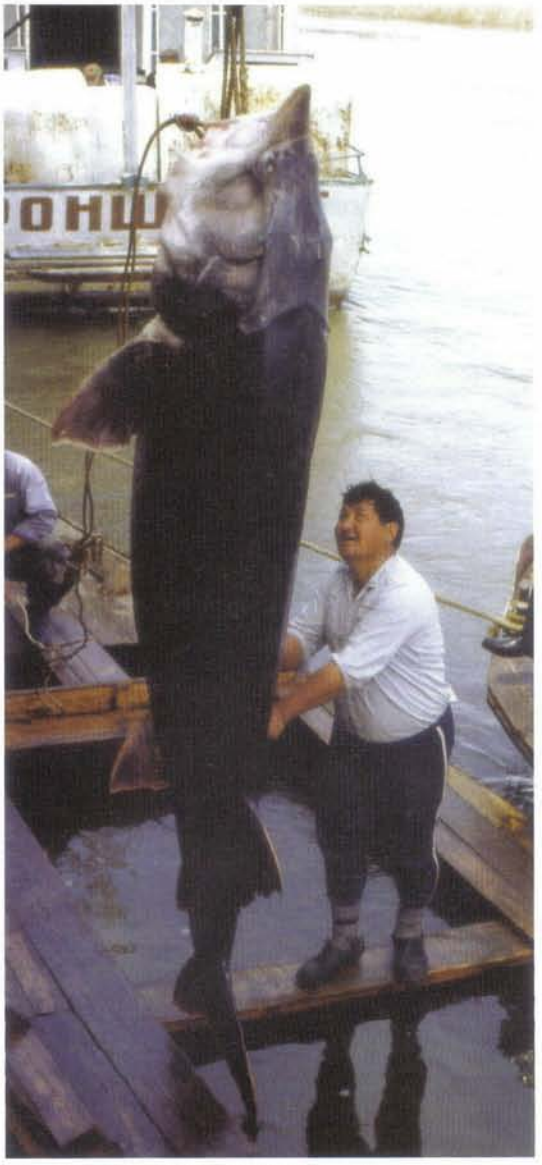
Distribution. Caspian, Black, Azov and Adriatic Sea basins.

Habitat. At sea, pelagic, following food organisms. Migrates further upriver to spawn than any other sturgeon (in Danube drainage up to Germany). Spawns in strong-current habitats in main course of large and deep rivers on stone or gravel bottom. Juveniles in shallow riverine habitats during first summer.

Biology. Anadromous. Males reproduce for the first time at 10–16 years, females at 14–20. Spawns every 3–4 years in April – June. A complicated pattern of spawning migrations includes one peak in late winter and spring and one in late summer and autumn. In spring, migrates from sea before spawning. Individuals migrating in autumn remain in river until the following spring. Yolk-sac larvae pelagic for 7–8 days and drift with current. Juveniles migrate to sea during their first summer and remain there until maturity. At sea, feeds on a wide variety of fish; even seals and birds have been reported as prey items.

Conservation status. CR A2d + 3d*. Extirpated from Adriatic (in the 1970s) and Azov Seas. Last population in Black Sea basin migrating to Danube. All other stocks almost extirpated due to overfishing and impoundment of spawning rivers. Stocked individuals still occasionally recorded from Azov and Black Seas. In Caspian basin, last wild population migrates up Ural River; Volga population depends on stocking as construction of Volgograd dam led to loss of almost all spawning sites. No natural spaning in Iranian waters. Most of the few recorded females in their first year of maturation. Overfishing for meat at sea and for caviar in estuaries will soon cause global extinction of the natural populations. In the immediate future, survival can only depend on stocking.

Further reading. Pirogovskii et al., in Holčík, 1989: 156 (biology).



Huso huso; Caspian Sea, Russia; ~3000 mm TL. G. Zauner

watermanⓒ

Family Polyodontidae

Paddlefishes

Distinguished by a long, paddle-like snout. Includes only *Psephurus gladius*, a piscivorous species from China (from Yangtze to Liao He drainages; close to extinction) and *Polyodon spathula*, a planktivorous species from U.S.A. (Mississippi drainage). *P. spathula* is cultivated in several countries (e.g. Russia, Greece, Hungary, Romania, Germany, Austria); in Russia it has been released in several water bodies where it is occasionally caught, but there is no evidence that it has established breeding populations. It reaches 2160 mm TL.

Further reading. Grande & Bemis, 1991 (osteology, phylogeny); Jenkins & Burkhead, 1993: 191 (biology).

Polyodon spathula; Mississippi drainage, U.S.A.; ~400 mm SL. A. Hartl

watermanⓒ

Family Anguillidae

Eels

Distinguished from any other eel-like fish in European freshwaters by its very elongate body, the dorsal, caudal and anal fins long and confluent, and no pelvic fins. Small family with about 15–20 species in a single genus (*Anguilla*), all catadromous (freshwater resident, migrating to spawn at sea). Species of *Anguilla* are known in all oceanic basins, except the Pacific slope of Americas. All species probably spawn in warm subtropical areas of deep seas.

The reproduction of eels has long been a mystery because sexually mature eels have not been found in European waters. Early ichthyologists thought that small gobies gave birth to young eel because they mistook parasitic nematodes for eel larvae; another belief, which lasted until the late 19th century was that eelpout *Zoarces viviparus* gave birth to small eels. In 1856, *Leptocephalus brevirostris* was first described from the Mediterranean, finally being recognized as larvae of *Anguilla* only in 1896. Larvae are called leptocephalus (plural leptocephali; Fig. 23). It was then hypothesised that the spawning sites were in the Mediterranean, but eel larvae smaller than 30 mm TL have never been observed there. In 1904, the first leptocephali were recorded outside the Mediterranean (Faroe Islands). Leptocephali smaller then 7 mm TL and yolk-sack larvae have been observed since, but only in the Sargasso Sea.

Two species of eels occur in the northern Atlantic: the European *A. anguilla* and the American *A. rostrata*; both spawn in the Sargasso Sea. Because of the long distance between European coasts and the Sargasso Sea, it had been hypothesised that adult European eels never reach the Sargasso Sea and that the European stocks recruit from American spawners; the morphological differences between European and American eels were considered to result from the different time spent at sea. This hypothesis was negated by the discovery that larvae of both species in the Sargasso Sea are distinguishable by their chromosomes and by enzyme electrophoresis.

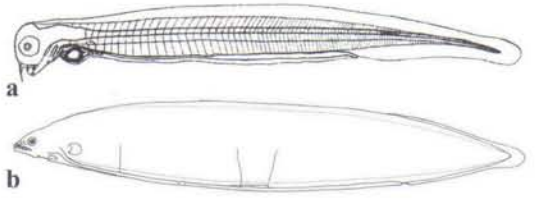


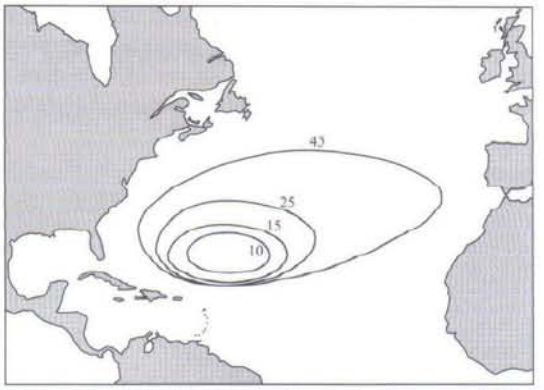
Figure 23 Leptocephalus larvae of Anguillidae. **a,** 6 mm; **b,** about 70 mm (after Schmidt, 1925; Moser et al., 1984).

Anguilla anguilla

Common name. European eel.

Diagnosis. Distinguished from all other fishes in European freshwaters by: ● body very elongate, slender, cylindrical / ● dorsal, caudal and anal long and confluent / ○ pelvic absent. Size usually about 400–600 mm TL, rarely larger, although individuals up to 2000 TL are reported.

Distribution. All European rivers draining to Mediterranean, North and Baltic Seas and to Atlantic south to Canary Islands. Very rarely entering White and Barents Seas, recorded eastward to Pechora. Small numbers enter Black Sea, migrating east to Kuban drainage. Occasional individuals reach Volga drainage through canals. Stocked in most inland waters. Large parts of the



Distribution of size-classes (in mm) of larvae of *Anguilla anguilla* in the Atlantic Ocean (after Schmidt, 1925).

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Anguilla anguilla; upper Rhine drainage, Germany; ~600 mm SL. A. Hartl

population remain at sea (northwestern Atlantic and Mediterranean).

Habitat. All types of benthic habitats from small streams to shores of large rivers and lakes. Naturally only in water bodies connected to sea, stocked elsewhere. Hypothesised to spawn only in Sargasso Sea, in western subtropical Atlantic (about 26°N 60°W). Spawning area is about 2000 km wide.

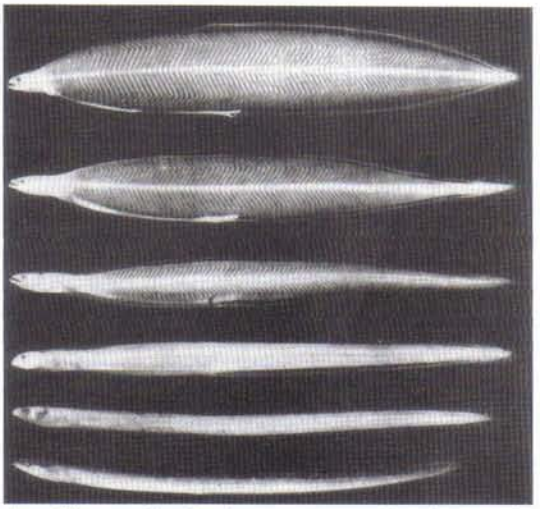
Biology. Catadromous. Spawning peaks at beginning of March, continuing until July. No concrete data about spawning sites, but suspected to be at a depth of 100–200 m and at approximately 20°C. Adults die after spawning. The mechanisms by which leptocephali reach European coasts are not well understood. There are indications that larvae swim actively and that drifting plays only a minor role. The well-known classical scheme of larval migration in the Gulf Stream is not supported by a statistical re-analysis of the data.

Leptocephali reach the continental slope at about 70 mm and metamorphose into glass-eels (almost adult appearance, but transparent body), which enter estuaries. Glass-eels are observed in autumn on Portuguese coasts, in winter in North Sea and in spring in Baltic Sea. Pigmentation increases during upriver migration and juveniles are then called elvers. The feeding phase lasts for 5–8 years in males and up to 12 years or more in females. Males are rarely recorded more than 200 km upriver. Downstream migration starts in late summer or autumn and adults arrive at spawning sites in the following spring. In males, eye diameter greatly increases before migration. Migrates in deep open water layers of the ocean, at about 300–700 m depth. Feeds on a wide variety of benthic organisms. Heavily infected by the nematode *Anguillicola crassus*, which feeds on blood in the swim-bladder; this parasite was introduced from Japan with experimental stocks of the Japanese eel *A. japonica*.

Conservation status. CR A2bd + 4bd. Sharply declining for unknown reasons. Adults and especially glass-eels overfished in several areas. There is no evidence that the decline is related to the infection by *A. crassus*..

Remarks. The American eel *A. rostrata* was stocked in eastern Europe. Although there is no established population, the presence of isolated individuals cannot be ruled out. *A. rostrata* is distinguished from *A. anguilla* by having fewer vertebrae (102–112, usually 106–108, vs. 111–119, usually 114–116).

Further reading. Schmidt, 1925 (breeding site); Boëtius & Harding, 1985 (migration); Tesch, 1999 (biology); Wirth & Bernatchez, 2001 (genetics); Dekker, 2003 (decline).



Anguilla anguilla; development stages, from leptocephalus to elver; figure from Schmidt's classical 1925 work.

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Family Clupeidae

Herrings, shads

A large family of pelagic fishes inhabiting all seas except the Antarctic. Clupeidae are one of the most important families for fisheries. Most species are marine, but many enter estuaries to forage or spawn, and some are anadromous or permanent fresh water inhabitants. Clupeids are distinguished from other European freshwater fishes by the presence of a ventral keel with scute-like scales forming a toothed edge when viewed in profile (Fig. 25), a large fleshy eye-lid, no lateral line and no adipose fin. Shads (*Alosa* species) and tyulkas (*Clupeonella* species) are commonly found in freshwaters, estuaries and coastal waters. Shads are mostly anadromous while tyulkas usually form resident populations in lakes or estuaries. Herrings (*Clupea* species) may enter brackish waters to spawn and are occasionally trapped in freshwaters along coasts of the Baltic, White and Barents Seas; they are not included here.

Alosa species are anadromous or form landlocked populations. They are very sensitive to environmental impacts resulting from impoundment, water pollution and overfishing. Most anadromous species have sharply declined during the 20th century. Species undertaking long upriver migrations, such as *A. alosa*, *A. immaculata* and *A. kessleri*, are very vulnerable as most of their original spawning sites are no longer accessible, their spawning migrations being interrupted by dams and other alterations in river morphology. The status of species or populations spawning in the lower stretches of rivers is somewhat better as they are able to find limited spawning habitats below dams. These include *A. algeriensis*, *A. caspia*, *A. fallax*, *A. maeotica*, *A. tanaica* and *A. volgensis*. Lacustrine species are very vulnerable to habitat alterations and fishing pressure.

The systematics of the European Clupeidae is in need of critical review. We recognize 4 species of *Clupeonella* in European freshwaters. This is tentative as the available data are contradictory and not presented so as to be unambiguously usable for reaching taxonomic conclusions. Data in the literature suggest that *C. abrau* is a distinct species restricted to a small lake; that *C. cultriventris* and *C. caspia* are genetically distinct although possibly not easily distinguished by external morphology; and that *C. tscharchalensis* from the Ural and Volga drainages is morphologically distinct. In recent years, a species of *Clupeonella* became invasive in the Volga and the Don drainage. It is assumed that *C. tscharchalensis* is the invading species and that it was introduced into the Don or reached it by canals, but this has not yet been satisfactorily investigated.

Further reading. Whitehead, 1985.

Key to genera of Clupeidae in European freshwaters

1a – Upper jaw with median notch (Fig. 24a); black lateral spots present in most individuals; elongated scales at base of caudal-fin lobes. ..... *Alosa*

1b – Upper jaw without median notch (Fig. 24b); no black lateral spots; no elongated scales at base of caudal-fin lobes. 2

2a – Last two anal rays of same length as preceding rays. ..... *Clupea*

2b – Last two anal rays longer than preceding rays and paddle-shaped (Fig. 25). ..... *Clupeonella*

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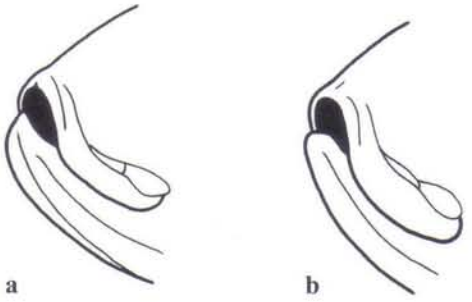

Figure 24 Upper jaw of Clupeidae: **a,** notched; **b,** not notched (after Whitehead, 1985).

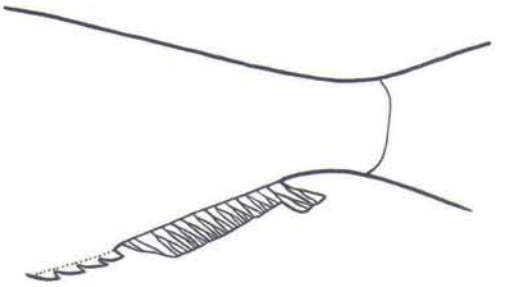

Figure 25 Paddle-shaped last two anal rays and scute-like scales in front of anal fin in *Clupeonella* species (after Whitehead, 1985).

Key to species of *Alosa* in European freshwaters

Caspian Sea basin

1a – 59–92 gill rakers, shorter than branchial filaments.
..... *A. kessleri*

1b – 70–180 gill rakers, about as long as or longer than branchial filaments.
..... 2

2a – Head length 23–26 % SL; 99–105 gill rakers, about as long as or longer than branchial filaments, with well-developed spines.
..... *A. volgensis*

2b – Head length 25–28 % SL; 70–180 gill rakers, long, and close together, 1.5–2 times longer than branchial filaments in individuals larger than 150 mm SL, without spines.
..... *A. caspia*

Black Sea basin

1a – Teeth on palatine and vomer absent or poorly developed.
..... 2

1b – Teeth on palatine and vomer well developed.
..... 3

2a – Teeth on palatine and vomer poorly developed; 66–96 gill rakers, longer than branchial filaments.
..... *A. tanaica*

2b – No teeth on palatine; 31–46 gill rakers (rarely up to 60) about as long as branchial filaments in individuals larger than 220 mm SL.
..... *A. fallax*

3a – 36–69 gill rakers, longer than branchial filaments.
..... *A. immaculata*

3b – 29–39 gill rakers, about as long as branchial filaments.
..... *A. maeotica*

Mediterranean basin

(Skadar landlocked species not included for lack of comparative data)

1a – Teeth on palatine and vomer well developed, especially in juveniles.
..... 2

1b – Teeth on palatine and vomer absent.
..... 3

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2a – 106–128 gill rakers.
..... *A. macedonica*
2b – 78–97 gill rakers.
..... *A. vistonica*

3a – 90–155 thin gill rakers.
..... *A. alosa*
3b – 31–72 gill rakers.
..... 4

4a – 31–50 thick gill rakers (rarely up to 60; different populations average between 33 and 48).
..... *A. fallax*
4b – 38–72 thin gill rakers.
..... 5

5a – Dorsal profile almost straight; 38–72 gill rakers in individuals larger than 120 mm SL (different populations average between 45 and 64); freshwaters; up to 340 mm SL (lakes of northern Italy, introduced to central Italy).
..... *A. agone*
5b – Dorsal profile convex; 40–60 gill rakers in individuals larger than 200 mm SL (different populations average between 47 and 51); anadromous; up to 430 mm SL (western Sardinia, Mediterranean coast from Tunisia to Morocco).
..... *A. algeriensis*

Atlantic, North and Baltic Seas

1a – 90–155 thin gill rakers, distinctly longer than branchial filaments in individuals larger than 250 mm SL.
..... *A. alosa*
1b – 31–53 gill rakers, about as long as or shorter than branchial filaments.
..... 2

2a – 31–50 thick gill rakers in individuals larger than 200 mm SL.
..... *A. fallax*
2b – 43–53 thin gill rakers in individuals larger than 150 mm SL.
..... *A. killarnensis*

Alosa agone

Common name. Agone.
Diagnosis. Distinguished from species of *Alosa* entering freshwater in Mediterranean basin by: ● dorsal profile almost straight / ○ 38–72 thin gill rakers (different populations average between 45 and 64) / ○ no teeth on palatine. Size up to 340 mm SL.
Distribution. Lakes Como, Garda, Orta, Maggiore, Lugano and Iseo (northern Italy, Switzerland). Introduced in Lakes Bolsena, Bracciano and Vico (central Italy).
Habitat. Lacustrine, pelagic.
Biology. Males reproduce for the first time at 2–3 years, females at 3–4. Most individuals reproduce only once or twice. Spawns when temperatures rise above 15–16°C in June – August, along shores near surface at night in bright moonlight. Feeds predominantly on cladocerans and copepods but also consumes small fish.
Conservation status. LC. Stocks seem to be safe in all lakes.
Remarks. Not a subspecies or variety of *A. fallax*. *A. f. lacustris* is a synonym.
Further reading. Quignard & Douchement, in Hoestlandt, 1991: 257 (as *A. f. lacustris*; biology), Kottelat, 1997: 36 (systematics); Bianco, 2002 (as 'landlocked form').

Alosa agone

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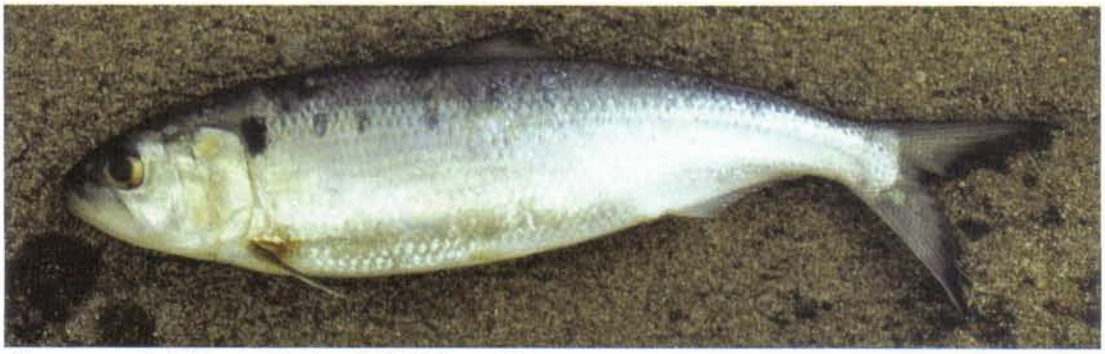

Alosa agone; Lake Lugano, Switzerland; 255 mm SL.

Alosa algeriensis; Oued Soummam, Algeria; ~220 mm SL. M. Bacha

Alosa algeriensis

Common name. North African shad.

Diagnosis. Distinguished from other species of *Alosa* entering freshwater in Mediterranean basin by: ○ dorsal profile convex / ○ 40–60 thin gill rakers in individuals larger than 200 mm SL (different populations average between 47 and 51) / ○ no teeth on palatine. Size up to 430 mm SL.

Distribution. In Europe, restricted to western Sardinia (Italy). Southwestern Mediterranean coast, from northern Morocco to northern Tunisia. Enters permanent rivers and coastal lagoons. Landlocked population in Lake Ichkeul (Tunisia) and in man-made lakes in Sardinia.

Habitat. Spawns close to estuaries in fresh and brackish water.

Biology. Anadromous. Males migrate upriver at 3–4 years, females at 4–5. Starts entering rivers when temperatures reach 14–18°C, mainly in May. Spawning commences when temperature rises above 20°C in May – June. Spent individuals migrate back to sea, but many die after spawning. Most juveniles migrate to river mouth in first summer and remain at sea until they mature. At sea, feeds predominant on crustaceans and small fishes. In freshwater, adults do not feed and juveniles prey on planktonic crustaceans.

Conservation status. DD.

Remarks. Earlier treated as a subspecies of *A. fallax*.

Alosa algeriensis

Alosa alosa

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Landlocked shads

There has been (and still is) debate about the status of the landlocked shads of northern Italy. At different times, some authors have considered the populations of each of the main Insubrian lakes (Maggiore, Lugano, Como, Iseo, Garda) to be different species or subspecies, or forming together a distinct species, or landlocked populations of the anadromous *A. fallax*. In the absence of contrary evidence, they constitute a single lineage that is diagnosably (morphological, habitat, life history and ontogeny characters) distinct from the anadromous *A. fallax* (and especially from the populations of the Adriatic basin to which these lakes belong), and so we treat them as a distinct species.

The theory that *A. fallax* trapped in freshwater evolved in a few generations into *A. agone* has no support. A population from Omodeo reservoir (western slope of Sardinia) trapped in freshwater by the construction of the dam in 1922 is referred to as anadromous *A. fallax* and is cited as proof of the ability of *A. fallax* to develop a landlocked form. The published facts are that between 1963 and 1999 there was a population in Omodeo reservoir with a given habitus, but there is no descriptive information of the population that inhabited the river in 1922; thus there is no documented change. The supposed difference between the landlocked population and the anadromous one in the same drainage refers only to gill raker counts and is minimal (landlocked: range 40–54, mean 47.9; anadromous: 42–50, mean 46.7) and both means are outside the values observed in *A. fallax* populations from southern France, mainland Italy and eastern Sardinia (39–45) but within those of *A. algeriensis* (47–51). This led us to consider these eastern Sardinina population as probably *A. algeriensis*. All this assumes that there have not been undocumented introductions.

In any case, the amplitude of the difference between the Sardinian landlocked and anadromous populations (mean 48, vs. 47 gill rakers) or between the Sardinian landlocked population and the Western Mediterranean *A. fallax* (mean 48, vs. 39–45) cannot be compared with the difference between *A. agone* and the Adriatic populations of *A. fallax* (mean 46–54, vs. 33–36).

Contrary to the Insubrian *A. agone*, the landlocked *Alosa* species from Lake Skadar and the sympatric Adriatic anadromous *A. fallax* have very close gill raker counts. *A. fallax* and *A. agone* do not occur in sympatry.

We are certainly far from the last word on shad systematics. Questions like: "are the Adriatic and western Mediterranean *A. fallax* conspecific? Are *A. algeriensis* and the western Mediterranean *A. fallax* conspecific?" are certainly justified. It would be pointless to seek answers only through gill-raker counts, as has been done too often. Shads are not merely 'swimming gill-raker counts': they have other morphological, biochemical, molecular and ontogenetic characters, which should also be investigated.

Further reading. Cottiglia, 1963a–b; Kottelat, 1997: 36; Rakaj & Crivelli, 2001; Bianco, 2002.

Further reading. Kartas, in Hoestlandt, 1991: 212 (biology); Kottelat, 1997: 37 (systematics).

Alosa alosa

Common name. Allis shad.

Diagnosis. Distinguished from other species of *Alosa* outside Caspian and Black Sea basins by: ● scales irregularly arranged on flank / ● 90–155 thin gill rakers / ○ gill rakers distinctly longer than branchial filaments in individuals longer than 250 mm SL / ○ no teeth on palatine / ○ usually a single large black blotch behind gill opening (sometimes missing, sometimes followed by several small blotches). Size up to 700 mm SL.

Distribution. Baltic, North and western Mediterranean Seas, Atlantic coast of Great Britain, Ireland, France, Spain, Portugal and Morocco from where adults ascend rivers, migrating far upstream to spawn. Earlier ascended Rhine for about 850 km up to Basel (Switzerland). Now, nearly extirpated east of Rhine, most abundant in Loire and Garonne drainages (France). Landlocked populations in some man-made lakes in Morocco and Portugal.

Habitat. At sea, pelagic, in deep water down to 300 m. Juveniles remain close to shore and to estuaries. Migrates from sea upriver, spawning in main river or entering large and warm tributaries. Spawning sites often situated near a confluence.

Biology. Anadromous. Males migrate upriver at 3–9 years. Females first reproduce 1–3 years later than males. Adults start approaching coasts at end of February and enter rivers when temperatures reach 10–12°C, usually in May. Spawning commences when temperature reaches 15°C. Optimal temperatures 22–24°C. Spawns in large, very noisy schools near surface at night. Eggs sink to bottom. Spent fish migrate back to sea, but most die after reproduction, having mated only once. Most juveniles migrate to river mouth during first summer

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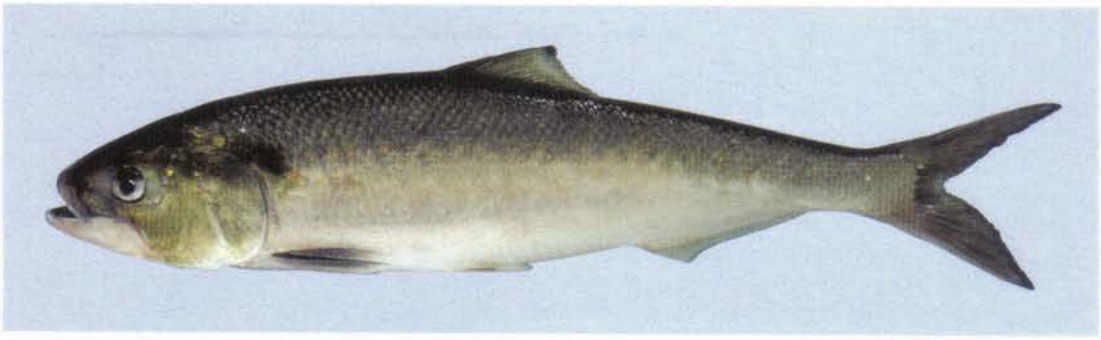
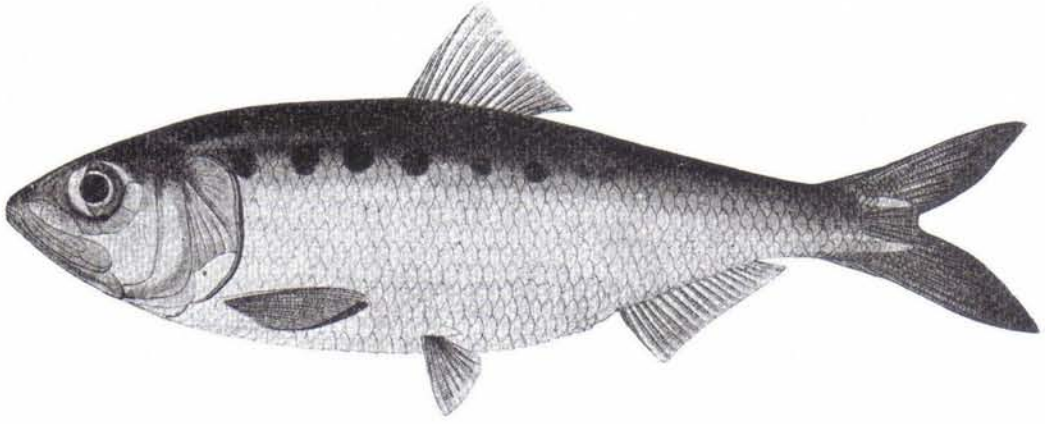


Alosa alosa; Upper Rhine, Germany; ~400 mm SL. M. Roggo

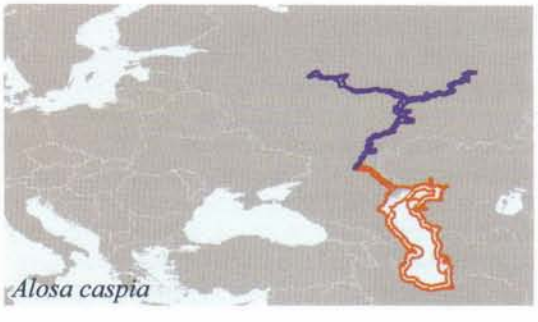


Alosa caspia; Caspian Sea, Russia; ~150 mm SL. (from Berg, 1932)

and remain at sea until they mature. Individual fish are thought to return to their natal spawning site. At sea, feeds predominantly on plankton. In freshwater, adults do not feed and juveniles prey on insect larvae.

Conservation status. LC. Presently only very locally distributed outside France, victim of pollution and impoundment of large rivers throughout Europe. Most populations declined during first decades of 20th century but seem to have stabilised at a low or medium level in recent times.

Further reading. Quignard & Douchement, in Hoestlandt, 1991: 89 (biology).



Alosa caspia

Alosa caspia

Common name. Caspian shad.

Diagnosis. Distinguished from other species of *Alosa* in Caspian Sea basin by: ● head length 25–28 % SL / ○ eye diameter 19–24 % HL / ○ pectoral length 16–18 % SL / ○ teeth on palatine and vomer poorly developed / ○ 70–180 gill rakers, long, and close together, 1.5–2 times longer than branchial filaments in individuals longer than 150 mm SL. Size up to 280 mm SL.

Distribution. Caspian Sea from where adults ascend rivers, migrating a short distance upstream to spawn.

Habitat. At sea, pelagic, in coastal waters with steady current, avoids areas with stable salinity. Migrates from sea to mouth of large rivers, spawns in fresh or slightly brackish water at shallow sites washed by flow of large rivers.

Biology. Anadromous. Males migrate upriver at 2–3 years, females at 4–5. Many individuals reproduce 2–4 seasons. There are two migration peaks, one in late April (mostly males) and one in early May (mostly females), entering rivers when temperature rises above 10°C. Spawns when temperature reaches 15°C or more, in May – June. Spawns usually in the upper 3 m. Eggs semipelag-

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Alosa fallax; lower Elbe, Germany; ~200 mm SL.

ic and demersal. Spent fish migrate back to sea. Juveniles migrate to sea during first summer, remaining at sea until they mature. At sea, feeds predominantly on zooplankton such as copepods and mysids.

Conservation status. LC.

Further reading. Heckman, in Hoestlandt, 1991: 135 (biology).

Alosa fallax

Common name. Twaite shad.

Diagnosis. Distinguished from other species of *Alosa* entering freshwater by: ○ 31–50 thick gill rakers (rarely up to 60) (population averages 41–48 in Atlantic, 39–45 in western Mediterranean, 33–36 in Adriatic) / ○ length of gill rakers equal to length of branchial filaments in individuals longer than 220 mm SL / ○ no teeth on palatine / ○ dorsal profile curved / ○ usually a series of 4–8 black blotches behind gill opening (sometimes a single blotch) / ○ scales regularly arranged on flank. Size up to 500 mm SL.

Distribution. Southern shore of Baltic, North Sea northward to Bergen, Atlantic coasts from Scotland and Ireland to Morocco, northern Mediterranean and rarely in northern Black Sea occasionally east to Crimea, from where adults ascend rivers, migrating a short distance upstream to spawn. Ascended Drin to Lake Ohrid. Earlier ascended Rhône for 600 km.

Habitat. At sea, pelagic. Juveniles remain close to shore and estuaries. Migrates from sea to rivers, spawns in main river often only few kilometres above limit of brackish water. Spawning also reported from small rivers over gravel bottom.

Biology. Anadromous. Males migrate upriver at 2–3 years, females at 3–4. Many individuals spawn 3–4 seasons. Adults congregate near estuaries in April and enter rivers when temperatures reach 10–12°C, mainly in May – June. Spawning starts when temperature reaches about 15°C or more, in May – June. Spawns in large, very noisy schools near surface after midnight. Eggs sink to bottom or are pelagic. Spent fish migrate back to sea. Most juveniles migrate to river mouth during first summer and move to sea at end of second year, where most remain until they mature. Individual fish are thought to return to their natal spawning site. At sea, feeds predominantly on crustaceans and small fishes. In freshwater, adults do not feed. Juveniles prey on planktonic crustaceans.

Conservation status. LC. Now only very locally distributed, a victim of pollution and impoundment of large rivers throughout Europe. Most populations declined during first decades of 20th century but seem to have stabilised at a low level since. Populations of estuaries of Weser and Elbe markedly increased during last 20 years.

Further reading. Quignard & Douchement, in Hoestlandt, 1991: 225, 265, 274 (biology; as *A. f. fallax*, *A. f. nilotica*, *A. f. rhodanensis*); Kottelat, 1997: 38 (systematics); Bianco, 2002 (biology; as *A. agone* 'migratory form').

Alosa immaculata

Common name. Black Sea shad.

Diagnosis. Distinguished from other species of *Alosa* entering freshwater in Black Sea basin by: ● 36–69 gill rakers, longer than branchial filaments / ○ teeth on palatine and vomer well-developed. Size up to 350 mm SL.

Distribution. Black and Azov Seas from where adults ascend rivers, migrating far upstream to spawn. Earlier ascended Danube for about 1600 km to Mohacs (Hungary), Don for 900 km to Oust-

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Alosa immaculata; South Bug, Ukraine; 217 mm SL.

Medveditskaya, Dniepr up to Kiev, Dniestr up to Yampol and South Bug up to Voznessensks. Since 1983, reported to spawn in Kuban below Krasnodar dam. A landlocked population in Don.

Habitat. At sea, pelagic, in deep water. Migrates to middle reaches of large rivers, spawning where current is strongest, close to surface, usually at 2–3 m depth in main channel.

Biology. Anadromous, migrating upriver to spawn at 3 years, rarely earlier. Only few individuals spawn two seasons. Appears along coast in March – April, enters rivers when temperatures reach about 6–9°C, between late March and late April. Migration usually peaks in May. Spawning starts when temperature rises above 15°C, in April – August. Spawns usually between 1 and 8 p.m. Eggs are pelagic. Spent individuals migrate back to sea to feed. Juveniles inhabit floodplain and shallow riverine habitats, migrate to the sea or estuarine habitats during first summer; in autumn, they move to the sea, remaining there until they mature. At sea, feeds on a wide variety of zooplankton (especially crustaceans) and small fish.

Conservation status. VU B2ab(v). Impoundment of main rivers has significantly reduced available spawning sites and migration routes. All populations declined during first decades of 20th century; decline seems to continue due to heavy overfishing. Largest population enters Danube.

Further reading. Kolarov, in Hoestlandt, 1991: 337 (biology; as *A. pontica*); Kottelat, 1997: 38 (systematics).

Alosa kessleri

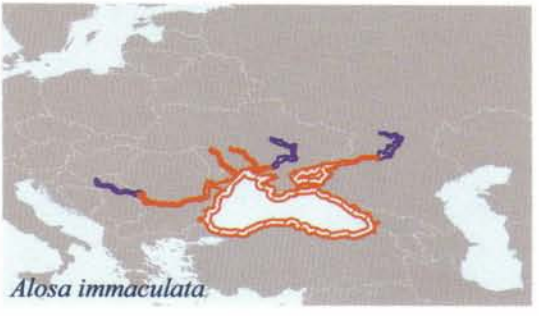
Common name. Black-back shad.

Diagnosis. Distinguished from other species of *Alosa* in Caspian Sea basin by: ● dorsum black in spring / ● teeth on palatine and vomer well-developed / ○ 59–92 thick gill rakers, shorter than gill filaments, with conspicuous lateral spines in juveniles but lost in adults / ○ head length 22–25 % SL / ○ eye diameter 15–20 % HL / ○ pectoral length 14–16 % SL. Size up to 400 mm SL.

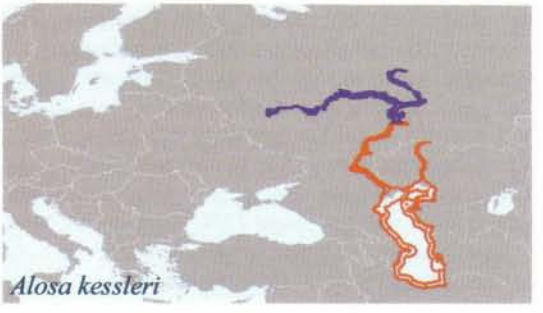
Distribution. Caspian Sea from where adults ascend Volga (only few fish enter Ural and Terek) to spawn. Earlier reached upriver up to Kama and Oka systems. Migrations now blocked by Volgograd dam. There are indications it has formed landlocked populations in Volga reservoirs.

Habitat. At sea, pelagic, in a wide variety of habitats. Migrates to middle reaches of large rivers, spawning close to shores in main channel and in almost-still water bodies such as river bays, river eddies and flood plains.

Biology. Anadromous. Migrates upriver to spawn at 4–5 years. Enters rivers with unripe gonads. Some spawn 2–4 seasons, but most females die after spawning. Spawners appear along the coast in March – April, entering rivers April – May when temperatures reach about 9°C, peaking at 12–15°C. Spawning run originally lasted 30–50 days. Spawning starts in May – August when temperature rises above 15°C, and lasts as long as temperatures remain at 15–23°C. Spawning is most intensive between 4 to 10 p.m. Eggs are bathypelagic. Spent



Alosa immaculata



Alosa kessleri

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Alosa kessleri; Volga delta, Russia; ~300 mm SL.

Alosa macedonica; Lake Volvi, Greece; ~140 mm SL.

fish migrate back to sea to feed. In autumn, they move to the southern part of the sea to overwinter. Juveniles migrate to the sea or to estuaries during their first summer, remaining there until maturity. At sea, feeds on a wide variety of zooplankton, crustaceans and small fish.

Conservation status. LC. Impoundment of main rivers has significantly reduced available spawning sites and migration routes. All populations declined during first decades of the 20th century; decline seems to continue due to heavy overfishing. Most spawning grounds were upriver of Volvograd and are no longer accessible. Largest population entering Volga and perhaps River Ural.

Further reading. Heckman, in Hoestlandt, 1991: 325 (biology).

Alosa killarnensis

Common name. Killarney shad.

Diagnosis. Distinguished from other species of *Alosa* entering freshwater in Atlantic basin by: ● 43–53 thin gill rakers at about 150–200 mm SL. Size up to 200 mm SL.

Distribution. Lough Leane (19 km^2) (Killarney, Eire).

Habitat. Lacustrine, pelagic, spawns in shallow bays.

Biology. Lives up to 5 years. Females are larger than males. Spawns in June – July on gravel bars and gravelled shallows around large islands of the lake. Feeds mostly on zooplankton.

Conservation status. CR B1ab(iii). Very small range. Threatened by eutrophication.

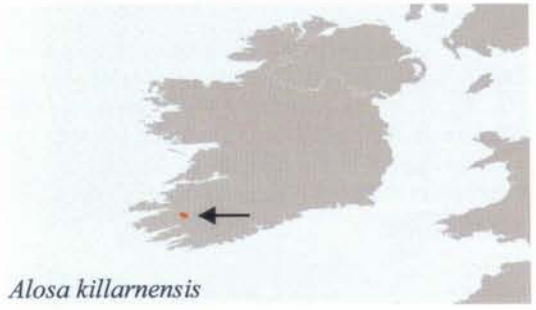
Further reading. O'Maoileidigh et al., 1988 (morphology); Doherty et al., 2004 (biology, conservation).

Alosa macedonica

Common name. Macedonian shad.

Diagnosis. Distinguished from other species of *Alosa* entering freshwater in Mediterranean basin by: O 106–128 gill rakers / O teeth on palatine and vomer well developed, especially in juveniles. Size up to 300 mm SL.

Distribution. Lakes Volvi (69 km^2, maximum depth 23 m) and Koronia (Greece).



Alosa killarnensis

Alosa macedonica

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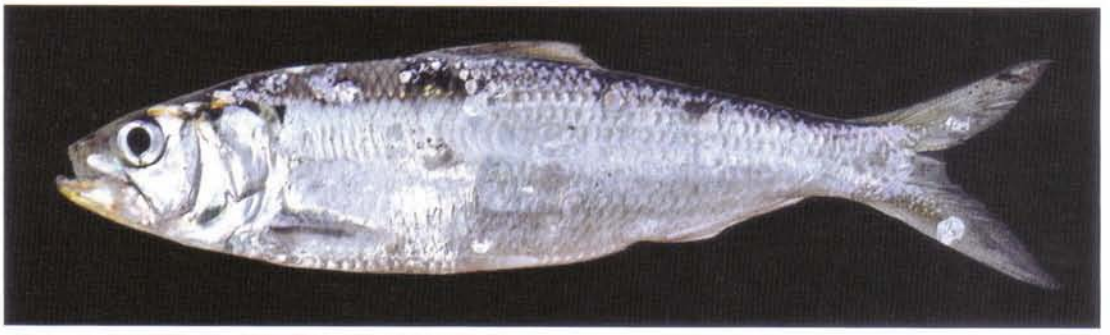
Alosa maeotica; Black Sea, Romania; ~250 mm SL.



Alosa tanaica; Danube delta, Romania; 149 mm SL.

Habitat. Lacustrine, pelagic, in upper water layers during summer, descending to deeper layers in winter. Spawns near shores above gravel or coarse sand.

Biology. Spawns at 1–2 years. Most individuals spawn more than one season. Spawning starts when temperatures reach about 19–20°C, in July – August. Feeds predominantly on cladocerans and copepods but also on small fish.

Conservation status. VU D2. Extirpated in Lake Koronia.

Further reading. Economidis & Sinis, 1986 (description); Economidis & Sinis, in Hoestlandt, 1991: 297 (biology); Kleanthidis & Sinis, 2001 (biology).

Alosa maeotica

Alosa maeotica

Common name. Azov shad.

Diagnosis. Distinguished from other species of *Alosa* entering freshwater in Black Sea basin by: ● 29–39 gill rakers, about as long as branchial filaments / ○ teeth on palatine and vomer well-developed. Size up to 280 mm SL.

Distribution. Black Sea and Sea of Azov, from where adults enter coastal lagoons to spawn.

Habitat. At sea, pelagic in deep water, entering brackish lagoons to spawn.

Biology. Spawns first at 2 years. Many individuals spawn 2–4 seasons. In Romania, spawners enter Lake Razelm when temperature reaches about 7°C, in March. Spawning starts when temperature reaches about 15°C, in late April – June. Eggs sink to bottom. Spent fish return to sea to feed. In autumn, migrates to southern Black Sea to overwinter. Juveniles migrate to sea or remain in estuaries during first summer. Feeds predominantly on small fish and crustaceans.

Conservation status. LC. Still more or less abundant in lower reaches of rivers and coastal lagoons. Decline in habitat quality in suitable estuarine ecosystems in northern Black Sea basin expected to have an impact in the immediate future.

Further reading. Kolarov, in Hoestlandt, 1991: 309 (biology).

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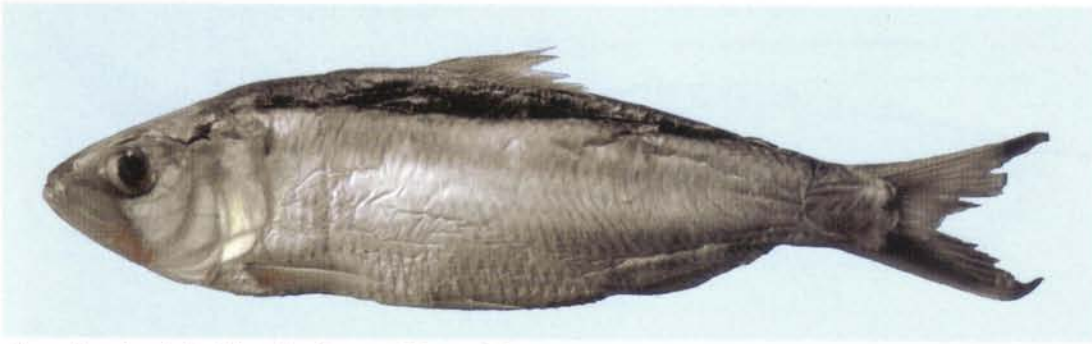

Alosa vistonica; Lake Vistonis, Greece; 126 mm SL.

Alosa tanaica

Common name. Black Sea shad.

Diagnosis. Distinguished from other species of *Alosa* entering freshwater in Black Sea basin by: ● 66–96 gill rakers, longer than branchial filaments / ● teeth on palatine and vomer poorly developed. Size up to 200 mm SL.

Distribution. Black and Azov Seas from where adults ascend rivers, migrating a short distance upstream to spawn.

Habitat. At sea, pelagic, in deeper layers (50–70 m) of coastal waters. Migrates from sea to mouth and lower reaches of large rivers, spawns in fresh or slightly brackish water, usually close to shore, in upper 2–4 m, in almost still water bodies as flood plains or lakes.

Biology. Anadromous. Migrates upriver at 1–2 years. Many individuals spawn 2–4 seasons. Spawners appear along coast in late January – March, enter rivers when temperature reaches about 10°C, in late April – May. Spawning starts when temperature reaches about 15°C or beyond, in May – June. Eggs are bathypelagic or sink to bottom. Spent fish migrate to estuaries and coastal lagoons or to sea near river mouths to feed. In autumn, they move to sea to overwinter. Juveniles migrate to sea or estuaries during first summer, remaining there until they mature. At sea, feeds on a wide variety of zooplankton (crustaceans), insect larvae and small fish.

Conservation status. LC. Most populations declined during first decades of 20th century due to water pollution. Seems to have stabilised at a moderate level in recent times. Decline in habitat quality in suitable estuarine ecosystems in northern Black Sea basin expected to have impact in the immediate. Still abundant in Azov Sea basin.

Further reading. Mogilchenko, in Hoestlandt, 1991: 181 (biology); Kottelat, 1997: 40 (systematics).

Alosa vistonica

Common name. Thracian shad.

Diagnosis. Distinguished from other species of *Alosa* entering freshwater in Mediterranean basin by: O 78–97 gill rakers / O teeth on palatine and vomer well developed, especially in juveniles. Size up to 170 mm SL.

Distribution. Lake Vistonis (Greece).

Habitat. Lacustrine, in a shallow lake, consisting of purely fresh water at its inland extremity and a brackish lagoon at the lower extremity. Inhabits mostly freshwater part.

Biology. No data.

Conservation status. CR A2ace; B1ab(iii,v). Thought extinct, but in 2005, fishermen reported the species to be still present in Lake Vistonis. Impacted by sewage, industrial effluents, alteration or destruction of spawning sites by agricultural development, and increased salinity following opening of a canal into the sea.

Further reading. Economidis & Sinis, 1986 (description); Economidis & Sinis, in Hoestlandt, 1991: 199 (habitat).

Alosa tanaica

Alosa vistonica

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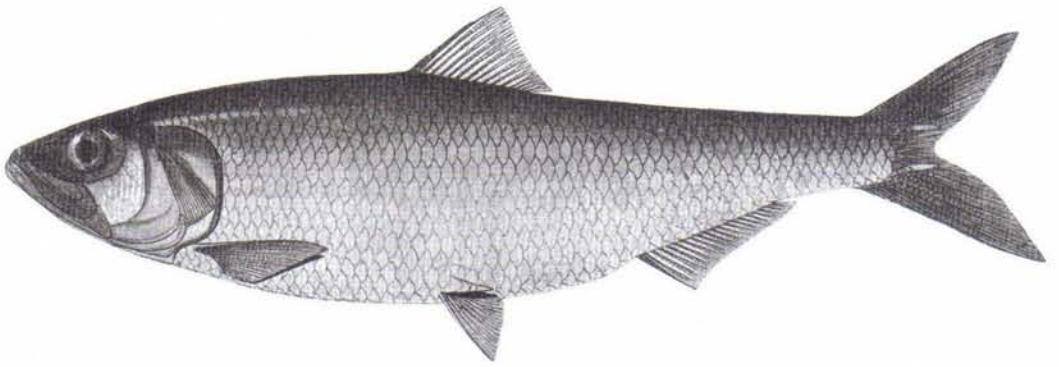


Alosa volgensis; Volga delta, Russia; ~350 mm SL. (from Berg, 1932)

Alosa volgensis

Common name. Volga shad.

Diagnosis. Distinguished from other species of *Alosa* in Caspian Sea basin by: ● dorsum light olive green in spring / ○ teeth on palatine and vomer poorly developed / ○ 99–105 gill rakers, about as long as or longer than branchial filaments, with well developed spines / ○ head length 23–26 % SL / ○ eye diameter 17–22 % HL / ○ pectoral length 14–19 % SL. Size up to 350 mm SL.

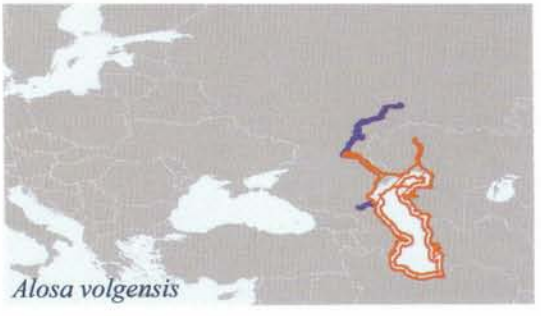
Distribution. Caspian Sea from where adults ascend Volga (only few fish enter Ural and Terek) to spawn. Does not penetrate far upstream, in Volga spawns between delta and Volgograd.

Habitat. Pelagic, in a wide variety of marine habitats. Migrates to delta and lower reaches of large rivers, spawns in main channel.

Biology. Anadromous. Migrates upriver to spawn at 2–3 years. Females spawn 2–3 times in their life. Appears in estuaries in April, enters rivers when temperature reaches about 9°C, in late April – early June with a peak at 17°C. Spawning run lasts 3–8 days. Enters rivers with ripe gonads. Spawning starts when temperature rises above 13°C, in late April – June, and continues as long as temperature remains below 27 °C. Eggs are pelagic. Spent fish migrate back to sea to feed. In autumn, moves to southern Caspian to overwinter. Juveniles migrate to sea during first summer, remaining there until maturity. At sea and during migrations, feeds on a wide variety of zooplankton (e.g. crustaceans) and small fish.

Conservation status. EN B2ab(iii,v). Largest population used formerly to enter the Volga, where it is extremely rare today. Impoundment of main rivers has significantly reduced available spawning sites and migration routes. All populations declined during the first decades of the 20th century; decline seems to continue due to heavy overfishing.

Further reading. Heckman, in Hoestlandt, 1991: 369 (biology).



Alosa volgensis

Alosa sp. Skadar

Common name. Skadar shad.

Diagnosis. Distinguished from sympatric *A. fallax* in Lake Skadar by: longer head (23–27 % SL, vs. 21–23), larger eye (4.5–6.5 % SL, vs. 3.5–5.0; 19–27 % HL, vs. 15–21), fewer gill rakers on lower limb of first gill arch (19–22, vs. 21–26; total count unknown). Size up to about 280 mm SL.

Distribution. Lake Skadar (Montenegro, Albania).

Habitat. Lacustrine.

Biology. Lives up to about 5 years. Spawns for the first time at 2 years. Spawns in June – July along shore, at temperatures around 23–28°C, on sand or gravel. Overwinters in deep water at northeastern part of lake in depressions fed by sublacustrine springs with constant temperature.

Conservation status. VU D2.

Remarks. Anadromous (*A. fallax*) and landlocked shads occur in sympatry in Lake Skadar. The landlocked one has a smaller maximum size (280 mm SL, vs. 500), spawns at 2–5 years (vs. 3–8) in June – July (vs. April – May) along the shore (vs. in middle of the lake) at 23–28°C (vs. 14–20). We tentatively treat this as a distinct species

Further reading. Rakaj & Crivelli, 2001 (biology; as *A. agone*).

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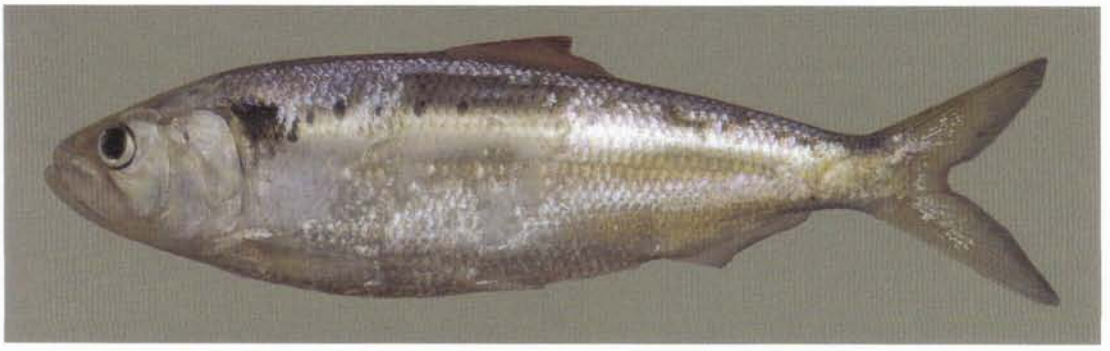

Alosa sp. Skadar; Lake Skadar, Montenegro; ~200 mm SL.

Key to species of *Clupeonella* in European freshwaters

1a – 49–62 gill rakers.
..... 2

1b – 36–52 gill rakers.
..... 3

2a – Depth of caudal peduncle 5–8 % SL; length of pelvic 8–13 % SL (Caspian Sea).
..... *C. caspia*

2b – Depth of caudal peduncle 7–9 % SL; length of pelvic 11–14 % SL (Black Sea).
..... *C. cultriventris*

3a – Body depth 19–23 % SL; depth of caudal peduncle 5–6 % SL (Lake Abrau).
..... *C. abrau*

3b – Body depth 21–29 % SL; depth of caudal peduncle 8–9 % SL (Caspian Sea, invasive in Black Sea).
..... *C. tscharchalensis*

Clupeonella abrau

Common name. Abrau tyulka.

Diagnosis. Distinguished from *C. cultriventris* and *C. tscharchalensis* (possibly invasive in Black Sea basin) by: ● depth of caudal peduncle 5–6 % SL / ○ body depth 19–23 % SL / ○ interorbital distance 16–18 % HL / ○ 39–50 gill rakers. Size up to 80 mm SL.

Distribution. Lake Abrau, near Novorossiisk (northern Caucasus, Russia).

Habitat. Lake Abrau is a warm and turbid lake, 2.6 × 0.6 km, 1.6 km^2, maximum depth 10 m, 84 m above sea level.

Biology. Pelagic. Lives up to 2 years. Spawns in open water, in late evening, in May – September. Eggs are pelagic. Feeds on crustaceans (copepods, mysids), following their daily vertical movements, swimming in surface layers at night and descending during daylight hours.

Conservation status. CR B1ab(ii,iii,v) + 2ab(ii, iii,v). Very small range. Lake Abrau is now the core of Lake Abrau Nature Reserve. However, up to 18 species have been reported to be introduced in the lake and *C. abrau* is now almost extinct.

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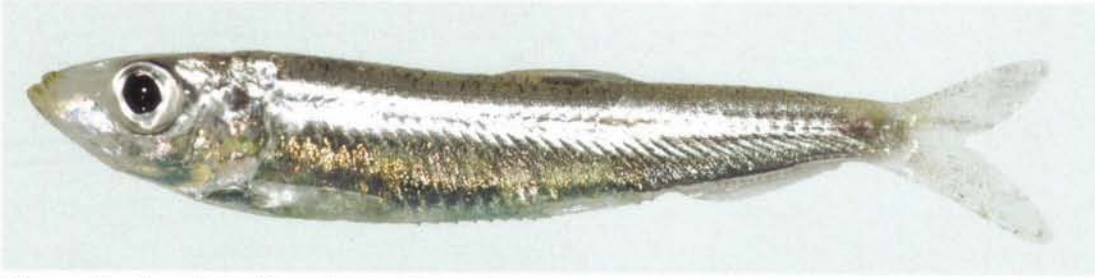

Clupeonella abrau; Lake Abrau, Russia; 65 mm SL. S. Tuniev

Clupeonella caspia, Caspian Sea, Iran, 90 mm SL. A. Abdoli

Remarks. *C. muhlisi* from Lake Apolyond (in Sea of Marmara basin in Turkey) usually considered as a synonym of *C. abrau* is a valid species.
Further reading. Mogilchenko, in Hoestlandt, 1991: 45 (biology).

Clupeonella caspia

Common name. Caspian tyulka.
Diagnosis. Distinguished from *C. tscharchalensis* entering freshwater in Caspian Sea basin by: ● 51–62 gill rakers / ● depth of caudal peduncle 5–8 % SL / O body depth 18–25 % SL / O length of pelvic 8–13 % SL. Size up to 120 mm SL.
Distribution. Caspian Sea and lower reaches of Volga, Ural and possibly Terek.
Habitat. At sea, pelagic. Spawns near river mouth.
Biology. Pelagic, marine or anadromous. Lives up to 6. Spawns in open water in late evening in April – July at 10–25°C. Pelagic eggs usually released in water 5 m deep and with a salinity of 0.02–15 ‰. Feeds on zooplanktonic crustaceans (copepods, mysids), following their daily vertical movements, in surface layers at night, descending during daylight hours.
Conservation status. LC. Reported to be abundant along shores of northern and western Caspian Sea.
Remarks. Earlier treated as a subspecies or variety of *C. cultriventris*.
Further reading. Kozlovsky, in Hoestlandt, 1991: 55 (biology); Kottelat, 1997: 41 (systematics).

Clupeonella cultriventris

Common name. Black Sea tyulka.
Diagnosis. Distinguished from *C. abrau* and *C. tscharchalensis* (possibly invasive in Black Sea basin) by: O body depth 21–27 % SL / O depth of caudal peduncle 7–9 % SL / O interorbital distance 18–22 % HL / O 49–62 gill rakers / O length of pelvic 11–14 % SL. Size up to 80 mm SL.
Distribution. Northwestern Black Sea and Sea of Azov.

Clupeonella caspia

Clupeonella cultriventris

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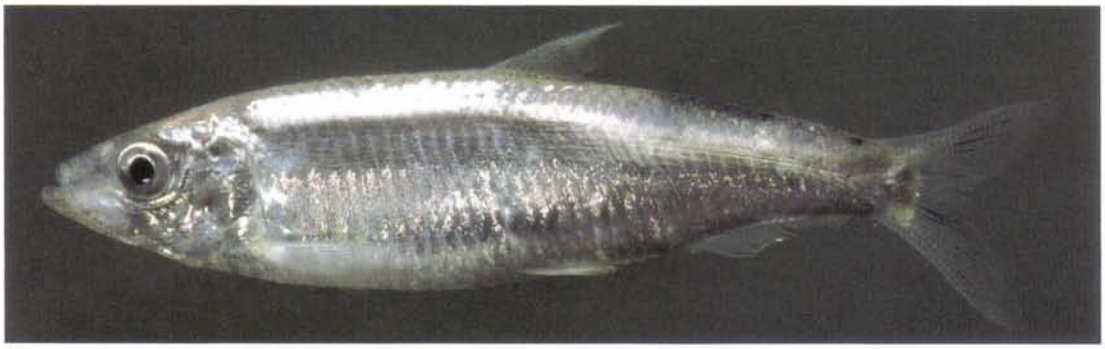


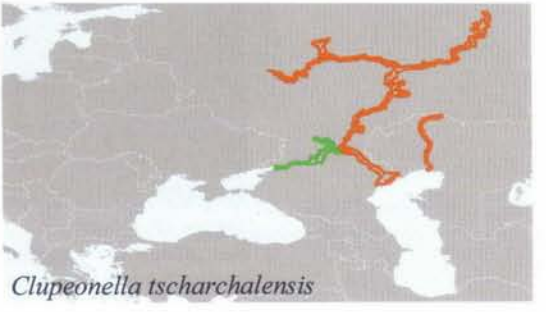
Clupeonella cultriventris; Lower South Bug, Ukraine; ~75 mm SL.

Clupeonella tscharchalensis; Lower Don, Russia; ~75 mm SL. A. Naseka

Habitat. Euryhaline, in coastal waters, lagoons and lakes, estuaries and lower reaches of large rivers with a salinity up to 13 ‰. Absent from pure seawater.
Biology. Pelagic. Lives up to 5 years. Spawns in open water in late evening in April – July at 10–18°C. Eggs are pelagic. In Azov Sea, there are two spawning runs, one in spring and one in autumn. Individuals migrating in autumn overwinter close to spawning sites and spawn in spring. Returns to sea after spawning. Juveniles migrate to sea during first summer. Feeds on crustaceans such as copepods and cladocerans.
Conservation status. LC. Abundant in lower reaches of rivers, coastal lakes and lagoons.
Further reading. Heckman, in Hoestlandt, 1991: 71 (biology); Kottelat, 1997: 41 (systematics).

Clupeonella tscharchalensis

Common name. Freshwater tyulka.
Diagnosis. Distinguished from *C. caspia* and *C. cultriventris* by: ○ 36–52 gill rakers / ○ body depth 21–29 % SL / ○ depth of caudal peduncle 8–9 % SL / ○ length of pelvic 8–13 % SL. Size up to 100 mm SL.
Distribution. Freshwater lakes, backwaters and reservoirs in Volga and Ural drainages. Invasive in middle Don drainage and in middle and upper Volga drainage, especially in River Kama.
Habitat. Pelagic zone of large freshwater lakes and reservoirs.
Biology. Pelagic. Lives up to 5 years. Spawns in open water in late evening, in April – July. Eggs are pelagic. Feeds on crustaceans such as copepods and cladocerans.
Conservation status. LC. Range expanding.
Remarks. Earlier treated as a subspecies or variety of *C. cultriventris*. The systematics of *Clupeonella* is not yet resolved. The identity of the species that is invasive in large dammed rivers of Black and Caspian Sea basins is not clear.
Further reading. Kozlovsky, in Hoestlandt, 1991: 67 (biology); Kottelat, 1997: 41 (systematics).



Clupeonella tscharchalensis

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Family Cyprinidae
Carps, minnows

A very large family of freshwater fishes found throughout the world with the exception of Madagascar, Australia, New Zealand and South America (although they have subsequently been introduced to these areas). They are distinguished by the 'teeth' in their throat known as 'pharyngeal teeth' (Figs. 26-27), which, in the absence of jaw teeth, are used to grind up the food against a masticatory pad on the basioccipital process of the cranium. Many species are important food fish.

The family includes about 2100 known species, which exhibit a large variety of shape (from herring-like *Pelecus cultratus* to massive *Carassius carassius*), habitats (from small springs in arid environments to Himalayan torrents) and modes of life. The relationships within the family are not yet fully understood and different authors have proposed different classifications and recognized different subfamilies, tribes, etc. Several lineages are quite easily recognized and it is not so much the composition of these lineages that is not well understood, but the relationships between them, their hierarchy, or the systematic rank (subfamily, tribe, etc.) assigned to them. The ranks are sometimes arbitrary and only a matter of convention. We give here subfamily rank to the lineages we recognize. Subfamily names, which frequently appear in the literature but are not retained here are: Xenocyprininae (for *Hypophthalmichthys*, *Xenocypris*, etc.), Barbinae (for *Barbus*, *Aulopyge*, etc.), Labeoinae, Rasborinae, etc.

Molecular genetic techniques, becoming increasingly fashionable and useful, have recently been applied to 'resolve' relationships within the Cyprinidae. Not surprisingly, the resulting publications have not yet succeeded in clarifying relatively many systematic problems: for the most part, they are uninformative. While the necessary molecular techniques are now available, it is necessary that researchers combine available data also on cyprinid diversity, anatomy, biology and zoogeography, reviewing also the large literature on the taxa concerned, before making conclusive systematic judgements.

The East Asian genus *Hypophthalmichthys* is tentatively included in the subfamily Leuciscinae. The East Asian subfamily Squaliobarbinae is included in the European fauna because two species

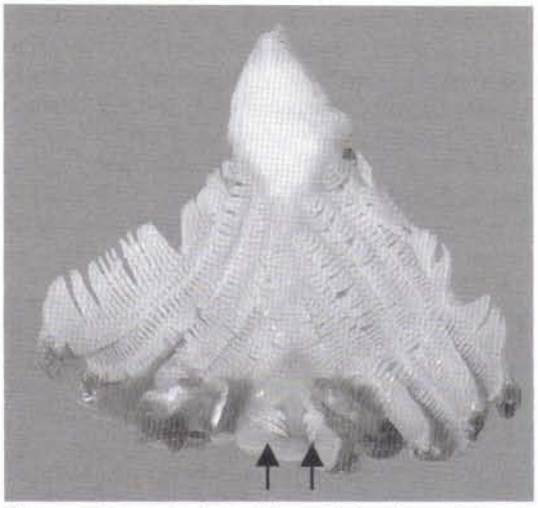

Figure 26 Dorsal view of branchial arches of *Carassius gibelio* showing four gill arches and one pharyngeal arch on each side; arrows point to pharyngeal teeth.

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Pharyngeal teeth in Cyprinidae

The pharyngeal teeth are located on the fifth gill arch or pharyngeal arch (gill arches 1–4 bear gill filaments and gill rakers) (Fig. 26). Their number, disposition and shape are useful characters to distinguish some species. To examine them, it is necessary to remove the pharyngeal arch. This dissection requires a little experience and training, magnification and good light.

The standard procedure is to extract a single pharyngeal arch, usually the right one, in order to retain intact the other side of the head. To extract the pharyngeal arch, the opercle is folded forward and a small, sharp tool (forceps, scalpel) is inserted between the arch and the anterior edge of the cleithrum. The tool is moved dorsally and ventrally along the cleithrum to cut the tissues surrounding the arch. The dorsal end of the arch is freed first. The arch is handled by its dorsal or ventral end and is moved back and forth to free it. It should not be seized by the middle as the tool would damage it or the teeth. The pharyngeal arches of small individuals are fragile, but firm handling is needed to extract them. Remaining tissues are removed from the arch and between the teeth, either manually or by soaking the arch in dilute KOH solution (0.5–1.0 %) (this should be done carefully as teeth of small species are easily broken while handling or damaged by the chemical).

Teeth are organised into 1–3 rows. All teeth in each row are counted, including broken and missing ones. Some teeth may be missing, either broken during the dissection or naturally (or in the process of being replaced). An empty socket identifies the position of a missing tooth. Teeth counts are given as a formula, in which the left arch count is given first, separated from the right one by a hyphen. For each side, the counts of teeth on the different rows are separated by commas, from outermost to innermost row of left arch, then innermost to outermost row of right arch. For example, the formula 1,3,5–5,2,1 indicates that there are three teeth rows on each arch, that the left one has 1 single tooth on the outer row, 3 on the median row, and 5 on the inner row, that the right arch has 1 single tooth on the outer row, 2 on the median row, and 5 on the inner row (Fig. 27).

The number of teeth may differ between the two sides of an individual (usually by one unit), generally with the left arch having more teeth. Within a species, pharyngeal teeth counts usually show little variability.

Pharyngeal teeth formulae, especially the number of rows, have often been used as a character to distinguish genera. The loss of teeth rows from 3 to 2 or 1 occurred independently in different lineages, especially during the evolution of small-sized species and genera, therefore this character cannot be used alone to define genera.

Pharyngeal teeth are regularly replaced and empty sockets in the pharyngeal arch might be the result of lost teeth. New teeth develop beside the pharyngeal arch, embedded in tissues and without contact with the bone. When growing, a new tooth becomes attached to the point of the pharyngeal arch occupied by the lost tooth.

Further reading. Jenkins & Burkhead, 1993: 138; Chu, 1935.

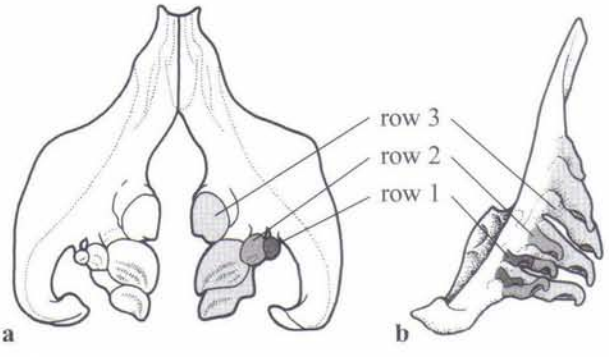

Figure 27 **a,** Dorsal view of pharyngeal arches of *Cyprinus carpio*, showing way of counting pharyngeal teeth (1,1,3–3,1,1 teeth). **b,** Anterodorsal view of left pharyngeal arch of *Barbus petenyi* (2,3,5–5,3,2 teeth) (after Holčík, 1989).

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Parabramis pekinensis; Guangzhou, China; ~300 mm SL. Zhou H.

Hemiculter leucisculus; Taiwan; 94 mm SL.

are frequently stocked, while the Asian subfamily Cultrinae is excluded. Cultrinae are characterised by a compressed body, a sharp keel on belly, a relatively long anal, often a spinous and rigid last simple dorsal ray and various osteological characters. One species (*Parabramis pekinensis*) is often listed as present in Lakes Prespa and Skadar. It was introduced to Albania for aquaculture and some individuals apparently escaped. It has not been seen for many years and apparently did not establish. A second species (*Hemiculter leucisculus*) was introduced to the Aral Sea basin and is actually invasive along the southern coast of the Caspian Sea. It has not yet reached European waters but should be expected.

Further reading. Winfield & Nelson, 1991; Cavender & Coburn, 1992; Arai & Kato, 2003.

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Key to subfamilies of Cyprinidae based on species native and introduced to Europe

1a – Two pairs of barbels.
..... Cyprininae

1b – No or one pair of barbels.
..... 2

2a – One pair of barbels.
..... 3

2b – No barbels.
..... 4

3a – 5–6½ branched anal rays; body cylindrical or slightly depressed, belly flattened; mouth inferior; a row of dark blotches on body.
..... Gobioninae

3b – Usually 7½ branched anal rays; body compressed; mouth terminal; body uniform greenish without blotches.
..... Tincinae

4a – 5–6½ branched anal rays.
..... 5

4b – 7–48½ branched anal rays
..... 6

5a – 7½ branched dorsal rays; 6½ branched anal rays; mouth superior; a dark grey stripe from eye to caudal base.
..... Gobioninae (*Pseudorasbora*)

5b – 14–21½ branched dorsal rays; 5½ branched anal rays; mouth terminal; no stripe.
..... Cyprininae (*Carassius*)

6a – Last simple dorsal ray spinous, rigid; belly keeled from pectoral base to anus; 27–30½ branched anal rays; pectoral not reaching to pelvic base.
..... Cultrinae

6b – Last simple dorsal ray neither spinous nor rigid (except *Pimephales promelas*, which has 7½ branched anal rays); belly rounded or with a keel starting behind pelvic origin (except *Pelecus cultratus*, which has very large pectoral, reaching beyond pelvic base).
..... 7

7a – Female with ovipositor; prominent dark stripe on posterior part of flank.
..... Acheilognathinae

7b – Female without ovipositor; if a stripe is present, then running from head or anterior body to caudal base.
..... 8

8a – Distance from anal origin to caudal base shorter than distance from anal origin to pelvic origin.
..... Squaliobarbinae

8b – Distance from anal origin to caudal base greater than or equal to distance from anal origin to pelvic origin.
..... Leuciscinae

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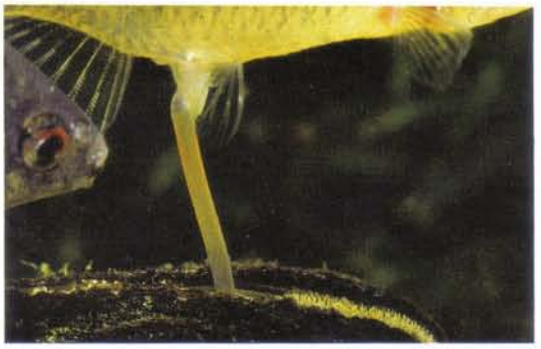
Subfamily Acheilognathinae

Bitterlings

A subfamily including about 40 species placed in 3 or 4 genera, distributed in Europe, west, east and southeast Asia. Two species are presently recognized in European waters. Acheilognathinae are deep bodied, compressed and small size fishes. Males have plates bearing tubercles on the snout. All species of Acheilognathidae have a complex reproduction cycle involving mussels. The female has a long flexible ovipositor, which is inserted into the mussel's outflow siphon to deposit a few eggs. When ready to spawn, the ovipositor and the muscular conical organ at its base are extended. A batch of eggs is positioned at the basal opening of the ovipositor, behind which urine collects. The female pushes the conical organ in the mussel's siphon. The conical organ contracts and the urine, under pressure, forces the eggs through the ovipositor. Oviposition is a very rapid process. At the same time, the male releases sperm into the inflow siphon. Eggs are oval, about 2.5–3 mm long, and are incubated within the gill chamber of the mussel. The yolk sac has lateral outgrowths, which allow the larvae to attach to the mussel's gills. Feeding larvae leave the mussel after 20–30 days. The larvae of the mussels (called glochidia) are obligate ectoparasites of fish. Bitterlings seem to be parasites of the mussels, whose growth they reduce while they avoid infection by glochidia.

Further reading. Arai & Akai, 1988 (systematics); Okazaki et al., 2001 (genetics).



Rhodeus amarus; Danube drainage, Germany; female with ovipositor, ~50 mm SL. A. Hartl

Rhodeus amarus

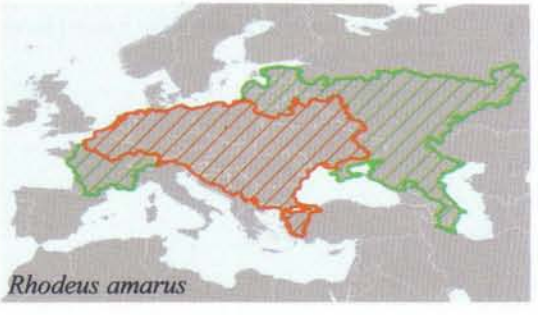
Common name. Bitterling.

Diagnosis. Distinguished from *R.meridionalis* by: ● mouth sub-inferior (vs. terminal) / ● rostral cap covering all or at least more than half of upper lip (vs. only upper part of upper lip). Size up to 95 mm SL.

Distribution. Basins of North, southern Baltic, Black, western and southern Caspian and Aegean Seas (from Maritza to Struma drainages); Mediterranean basin, only in northern Rhône (France) and Drin drainages (Albania, Montenegro, Macedonia). Invasive in France in southern Rhône and west of Seine, in southern Russia in Don and Kuban drainages. Introduced to Crimea, Great Britain and northern Italy. Absent in River Ural, Denmark, Scandinavia, Iberian and Apennine Peninsulas, most of Adriatic basin and Black Sea basin south of Kuban drainage.

Habitat. Most abundant in still or slow-flowing water with dense aquatic vegetation and sand-silt bottom as lowland ponds, canals, slow-flowing rivers, backwaters and oxbows, where mussels are present.

Biology. Spawns for the first time at 1 year and about 30–35 mm SL. Lives exceptionally up to 5 years but most individuals do not survive the year of their first reproduction and population sizes fluctuate greatly over the years. Spawns in April – August at water temperatures above 15°C. Males defend small territories around one or a few mussels (mostly *Unio* and *Anodonta* spp.), moving with mussels. Females select mussels with high oxygen concentrations in exhalant siphon. They avoid mussels already containing high numbers of *R.*



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Rhodeus amarus; Danube drainage, Germany; male, ~50 mm SL. A. Hartl

Rhodeus amarus; oviposition; Danube drainage, Germany; male (left) and female (right, with ovipositor), ~50 mm SL. A. Hartl

amarus larvae or gravid with glochidia (the mussel's own larvae). They also avoid *Anodonta cygnaea*, which is able to eject most eggs and larvae and usually has low oxygen concentrations in its outflow siphon. Males show pre-oviposition ejaculation, when females inspect or approach the mussel. After spawning, sneaking males try to fertilise the eggs. Females usually lay 80–250 eggs per year, spawn up to 5 times in season. Developing larvae remain inside the mussel for about 1 month. Larvae show adaptations to very low oxygen concentrations in the mussel, such as very fast hatching (36 h) and enlarged cutaneous respiratory system. Wing-like yolk projections hold the larvae in the mussel's gills. Apparently, *R. amarus* and mussels have a parasitic relationship. Mussels suffer a reduction in fitness carrying *R. amarus* larvae. Larvae and mussels compete for oxygen

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Rhodeus meridionalis; Pinios (Thessaly), Greece; male, ~70 mm SL.

and larvae seem to inhibit free water circulation through the mussel's gills and may damage them. *R. amarus* is very rarely infected by glochidia (ectoparasitic mussel larvae). Feeds predominantly on algae, diatoms and other plant material. Commonly translocated, bred and used for human pregnancy tests prior to the development of modern techniques, and this resulted in numerous introductions. Females injected with urine from a pregnant woman protrude their ovipositor.

Conservation status. LC. Abundant and expanding in most of its range. Locally threatened by water pollution, weed clearing, and stocking of predatory fish.

Remarks. Considered conspecific with the East Asian *R. sericeus* by some authors; the two species have widely disjunct ranges. There are undocumented records of introduction of the Chinese *R. ocellatus* in Germany. *R. ocellatus* is distinguished by having 10–12½ branched dorsal rays (vs. 9½, 10½, in *R. amarus*) and females and juveniles with a black blotch in anterior part of dorsal (vs. no blotch). *Rhodeus* from Asian Black Sea basin in Russia and Georgia (and possibly Anatolian ones too) belong to *R. colchicus*.

Rhodeus meridionalis

A recent study suggests that the native range was restricted to the middle and lower reaches of northern Black Sea tributaries. It spread with the introduction of carp culture in the Middle Age. This information arrived too late to be included in the map.

Further reading. Holčík & Jedlicka, 1994 (morphology); Kottelat, 1997: 75 (systematics); Holčík, in Bănărescu, 1999: 2 (biology); Bogutskaya & Komlev, 2001 (morphology); Smith et al., 2004 (reproduction; as *R. sericeus*); Bohlen et al., 2006 (genetics); Van Damme et al., 2007 (invasion).

Rhodeus meridionalis

Common name. Vardar bitterling.

Diagnosis. Distinguished from *R. amarus* by: ● mouth terminal (vs. sub-inferior) / ● rostral cap covering upper part of upper lip (vs. upper lip covered completely or more than half). Size up to 95 mm SL.

Distribution. Aegean Sea: from Vardar south to Pinios drainages.

Habitat. Large to medium sized rivers and still waters as ponds, lakes, canals and backwaters.

Biology. No data, likely to be similar to *R. amarus*.

Conservation status. LC.

Remarks. Recognised mostly on the basis of genetic differences. The mouth characters mentioned in diagnosis might be of limited value. The western Palearctic *Rhodeus* form a group of morphologically very similar species, which have long been considered to be conspecific. Recent molecular data support the distinctness of *R. meridionalis* and probably additional species.

Further reading. Bohlen et al., 2006 (genetics).

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Subfamily Gobioninae

Gudgeons

Gobioninae are a quite distinctive lineage within the family Cyprinidae, and it has occasionally been suggested that they could be regarded as a distinct family. They are collectively known as gudgeons [note: in Australia, the word gudgeon is used for unrelated fishes belonging to the families Eleotrididae and Gobiidae]. Gobioninae are most diverse in east Asia, from the Amur drainage southward to Central Vietnam; some 23 genera and 130 species are known. Gudgeons are easily distinguished from other European cyprinids. They are benthic fishes, with a flat belly, laterally spread pectoral fins, 7–8½ branched dorsal rays, an inferior mouth, a single pair of maxillary barbels, and 6½ branched anal rays (a single European species has 5½). Some Asian genera look very different from true gudgeons; they have a more compressed body, the mouth is inferior to subterminal (even superior in *Pseudorasbora*); they are distinguished from other east Asian cyprinids by having 6½ branched anal rays. Some species of *Sarcocheilichthys* are noteworthy for spawning in the gill cavity of unionide freshwater mussels, similar to European and Asian bitterlings (*Rhodeus* and other genera); they too have developed an ovipositor. One Asian species, *Pseudorasbora parva*, was accidentally introduced to Europe and is now well established. All European and many Asian true gudgeons are superficially very similar bottom dwelling, small fishes with a midlateral row of dark blotches on flank and spotted body and fins.

Further reading. Bănărescu & Nalbant, 1973 (systematics); Chen, 1998 (systematics).

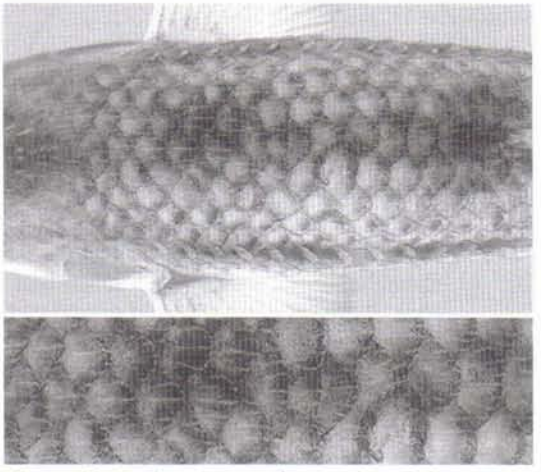

Figure 28 Predorsal area of a species of *Romanogobio* showing scales with epithelial crests in Gobioninae. The crests are not part of the scale but ornamentations of the skin covering the scale and are easily abraded.

Key to genera of Gobioninae in Europe

1a – Barbels absent; mouth superior. ..... *Pseudorasbora*

1b – Barbels present; mouth inferior. 2

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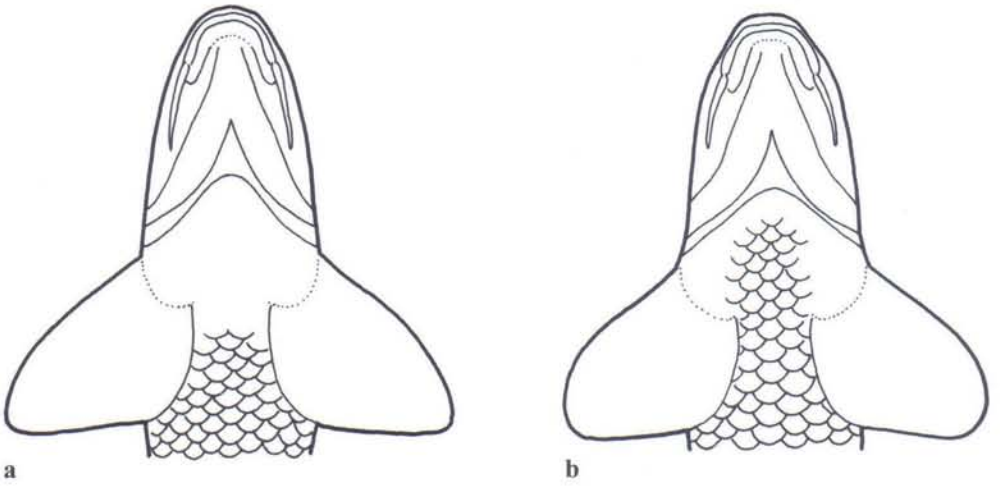

Figure 29 Ventral view of *Gobio* species; **a,** scales extending forwards only to posterior extremity of pectoral base; **b,** scales extending forward beyond pectoral origin.

2a – Epithelial crests on scales on dorsal half of body (Fig. 28; except *R. uranoscopus*, *R. pentatrichus*, *R. benacensis*); depth of caudal peduncle 2.6–4.2 times in its length, smaller than or equal to body width at posterior extremity of base of anal (except *R. benacensis*); anus closer to pelvic base than to anal origin, or midway (except in *R. uranoscopus*, *R. elimeius* and *R. pentatrichus*).
..... *Romanogobio*

2b – No epithelial crests on scales on dorsal half of body; depth of caudal peduncle 1.4–2.7 times in its length, usually greater than or equal to body width at posterior extremity of base of anal; anus closer to anal origin than to pelvic base.
..... 3

3a – Distance between anus and anal origin equal to or greater than eye diameter; 4–8 scales between anus and anal origin.
..... *Gobio*

3b – Distance between anus and anal origin distinctly smaller than eye diameter; 2–4 scales between anus and anal origin.
..... 4

4a – Scales on belly extending forward to a point between pectoral and pelvic bases (Italy, Slovenia).
..... *Romanogobio benacensis*

4b – Scales on belly extending forward beyond origin of pectoral (Thessaly, Thessaly).
..... *Gobio feraeensis*

Key to species of *Gobio* in Europe

Iberian Peninsula, France, Great Britain, and North and Baltic Sea basins

1a – ½5 scale rows between dorsal origin and lateral line; 3–3½ scale rows between lateral line and pelvic origin (France [Adour drainage], Spain, Portugal).
..... *G. lozanoi*

1b – ½6–7 scale rows between dorsal origin and lateral line; 3½–4½ scale rows between lateral line and pelvic origin.
..... 2

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2a – Scales on belly extending forward at most to posterior extremity of pectoral base (Fig. 29a).
..... *G. gobio*

2b – Scales on belly extending forward beyond origin of pectoral (Fig. 29b).
..... 3

3a — Interorbital area concave in individuals larger than 80 mm SL; 16 circumpeduncular scale rows; last simple dorsal ray shorter than first branched one; posterior margin of dorsal straight to slightly concave (Garonne and upper Loire drainages, France).
..... *G. alverniae*

3b — Interorbital area flat to convex; 12–15 (rarely 16) circumpeduncular scale rows; last simple dorsal ray longer, as long or slightly shorter than first branched one; posterior margin of dorsal distinctly concave (Languedoc, France).
..... *G. occitaniae*

Adriatic and Aegean Sea basins

Including the similar looking *Romanogobio benacensis*.

1a — Distance between anus and anal origin distinctly smaller than eye diameter; 2–4 scales between anus and anal origin.
..... 2

1b — Distance between anus and anal origin equal to or greater than eye diameter; 4–6 scales between anus and anal origin.
..... 3

2a — Scales on belly extending forward to a point between pectoral and pelvic bases (Italy, Slovenia).
..... *Romanogobio benacensis*

2b — Scales on belly extending forward beyond pectoral base (Thessaly, Greece).
..... *G. feraeensis*

3a — Scales on belly extending forward beyond pectoral base (Fig. 29b) (from Aliakmon to Maritza).
..... *G. bulgaricus*

3b — Breast naked between pectorals or with a single scale row along midline (Fig. 29a).
..... 4

4a — 39–42 + 2 lateral line scales (introduced).
..... *G. gobio*

4b — 36–39 + 2–3 lateral line scales.
..... 5

5a — Head length 29–34 % SL; snout length 40–45 % HL; 7–10 midlateral blotches, irregularly set and shaped (Lake Ohrid).
..... *G. ohridanus*

5b — Head length 27–30 % SL; snout length 34–42 % HL; 6–7 midlateral blotches, often grouped two by two (Lake Skadar basin).
..... *G. skadarensis*

Black and Caspian Sea basins

Several species are morphologically quite similar and distinguished by appearance —difficult to express by words— and subtil morphometric differences. Molecular data, however, confirm they are distinct. Most species are allopatric and the geographic origin is a good starting point for identification.

1a — Breast naked between pectorals (Fig. 29a) or breast with 1–2 scale rows along midline.
..... 2

1b — Breast scaled between pectorals in most individuals, scales not restricted to midline, scales often deeply embedded in skin (Fig. 29b).
..... 6

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2a — Barbel reaching to anterior eye margin; head width 13–15 % SL (Don drainage).
..... *G. brevicirris*

2a — Barbel reaching beyond anterior eye margin; head width 14–19 % SL.
..... 3

3a – Head depth 16–18 % SL.
..... 4

3b – Head depth 14–17 % SL.
..... 5

4a – Depth of caudal peduncle 29–34 % HL; head width 54–61 % HL; snout length 0.8–0.9 times in postorbital distance (lower Dniestr and South Bug drainages).
..... *G. sarmaticus*

4b – Depth of caudal peduncle 36–44 % HL; head width 59–69 % HL; snout length 0.9–1.2 times in postorbital distance (middle and upper Danube drainage).
..... *G. obtusirostris*

5a – Eye diameter 1.0–1.4 times in interorbital distance in individuals over about 60 mm SL (less in smaller ones), 5–7 % SL (at 70–90 mm SL), 2.4–2.8 times in head depth; head width 49–57 % HL; barbel reaching middle of eye (upper Danube, Dniepr and Dniestr drainages).
..... *G. gobio*

5b – Eye diameter 1.4–1.7 times in interorbital distance in individuals over about 60 mm SL (less in smaller ones), 4–6 % SL (at 70–90 mm SL), 2.7–3.4 times in head depth; head width 56–63 % HL; barbel reaching between middle of eye and posterior eye margin (Tisza, Danube drainage).
..... *G. carpathicus*

6a – Barbel reaching to or beyond posterior eye margin in most individuals, its length 25–42 % HL.
..... 7

6b – Barbel not reaching to posterior eye margin, its length 13–27 % HL.
..... 9

7a – Pectoral reaching to or 1 scale in front of pelvic origin in mature males (Caspian basin).
..... *G. holurus*

7b – Pectoral reaching 3–4 scales in front of pelvic origin in mature males (Black Sea basin).
..... 8

8a – Head length 24–26 % SL; body width 1.4–1.7 times in body depth; barbel length 35–42 % HL (Kuban drainage).
..... *G. kubanicus*

8a – Head length 26–28 % SL; body width 1.1–1.6 times in body depth; barbel length 25–35 % HL (Provadiskaya, Bulgaria).
..... *G. kovatschevi*

9a – Mature males with numerous dark grey pigments on belly; 6–9 (usually 7–8) scales between anus and anal origin; barbel reaching to or slightly in front of anterior eye margin, its length 13–22 % HL, 2.0–3.3 times in snout length (Chornaya, Crimea).
..... *G. delyamurei*

9b – Mature males with belly whitish; 4–8 (usually 5–6) scales between anus and anal origin; barbel reaching beyond anterior eye margin, often to middle of eye, its length 19–27 % HL, 1.6–2.3 times in snout length (Crimea; Salgir, Alma and Bel Bek) (short-barbel *G. kubanicus* key here; see species account).
..... *G. krymensis*

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Gobio alverniae; Loire drainage, France; 106 mm SL.

Gobio brevicirris; lower Don, Russia; 100 mm SL.

Gobio alverniae

Common name. Auvergne gudgeon.

Diagnosis. Distinguished from other species of *Gobio* in Europe by: ❍ interorbital area markedly concave in individuals over 80 mm SL / ❍ 5 scales between anus and anal origin / ❍ head length 25–29 % SL / ❍ breast scaled forward until in front of pectorals / ❍ 38–40 + 2–3 lateral line scales / ❍ 4 scale rows between lateral line and pelvic origin / ❍ eye diameter 1.4–1.7 times in interorbital distance / ❍ depth of caudal peduncle 1.6–2.2 times in its length / ❍ midlateral blotches not conspicuous, not contrasted and with fuzzy margins / ❍ 16 circumpeduncular scale rows. Size up to 150 mm SL.

Distribution. France: upper Loire, Dordogne, Lot and Tarn drainages.

Habitat. Streams in hilly area with moderate to swift current.

Biology. No data.

Conservation status. LC, small range, possible introgression and impact of dams are a concern.

Further reading. Kottelat & Persat, 2005: 220 (description).

Gobio brevicirris

Common name. Don gudgeon.

Diagnosis. Distinguished from other species of *Gobio* in Black and Caspian Sea basins by: ❍ barbel reaching to anterior eye margin / ❍ breast naked between pectorals / ❍ snout length greater than postorbital distance / ❍ head length 23–28 % SL / ❍ head depth at nape 14–15 % SL, at eye 45–54 % HL / ❍ body depth 18–22 % SL / ❍ head width 13–15 % SL, 49–64 % HL / ❍ eye diameter 4–6 % SL, 2.8–3.2 times in head depth, 1.3–1.5 times in interorbital distance (at 80–100 mm SL) / ❍ depth of caudal peduncle 29–39 % HL. Size up to about 100 mm SL.

Distribution. Russia and Ukraine: river Don.

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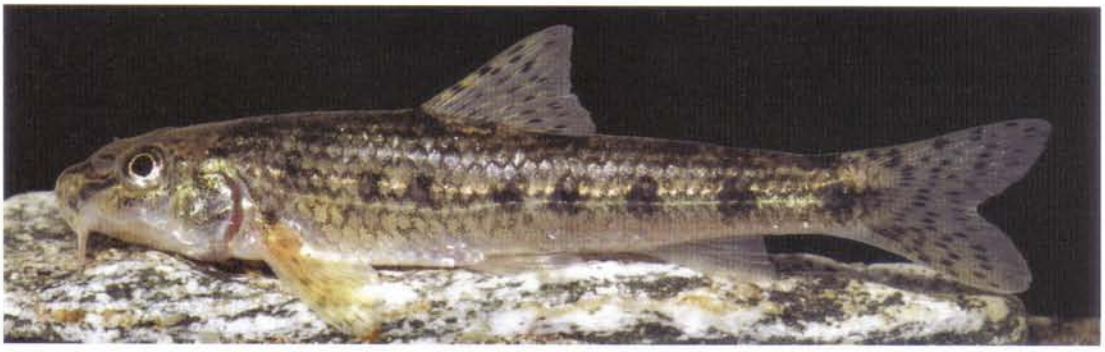

Gobio bulgaricus; Maritza, Greece; ~75 mm SL.

Gobio carpathicus; Mureş, Danube drainage, Romania; ~75 mm SL.

Habitat. A wide variety of habitats in rivers and streams.
Biology. No data.
Conservation status. LC.
Further reading. Berg, 1949: 642 (description).

Gobio bulgaricus

Common name. Aegean gudgeon.
Diagnosis. Distinguished from other species of *Gobio* in Adriatic and Aegean Sea basins by: ○ 4–6 scales between anus and anal origin / ○ head length 25–29 % SL / ○ breast scaled between pectorals, scales extending forward beyond base of pectoral (at least in some individuals of any population) / ○ usually 35–38 + 3 lateral line scales / ○ 14–16 circumpeduncular scale rows / ○ eye diameter 1.1–1.5 times in interorbital distance. Size up to about 90 mm SL.
Distribution. Aegean basin, from Maritza to Aliakmon drainages (Turkey, Bulgaria, Greece, Macedonia).
Habitat. Stretches of streams and rivers with moderate flow, usually sand bottom.
Biology. No data.
Conservation status. LC.
Remarks. The populations from Maritza and Vardar drainages may represent two species (*G. bulgaricus* and *G. balcanicus*), but the published data are not conclusive.
Further reading. Bănărescu & Nalbant, 1973: 117 (systematics); Dimovski & Grupče, 1977 (morphometry; as *G. gobio balcanicus*).

Gobio carpathicus

Common name. Carpathian gudgeon.
Diagnosis. Distinguished from other species of *Gobio* in Black and Caspian Sea basins by: ○ breast naked between pectorals or only a few

Gobio bulgaricus

Gobio carpathicus

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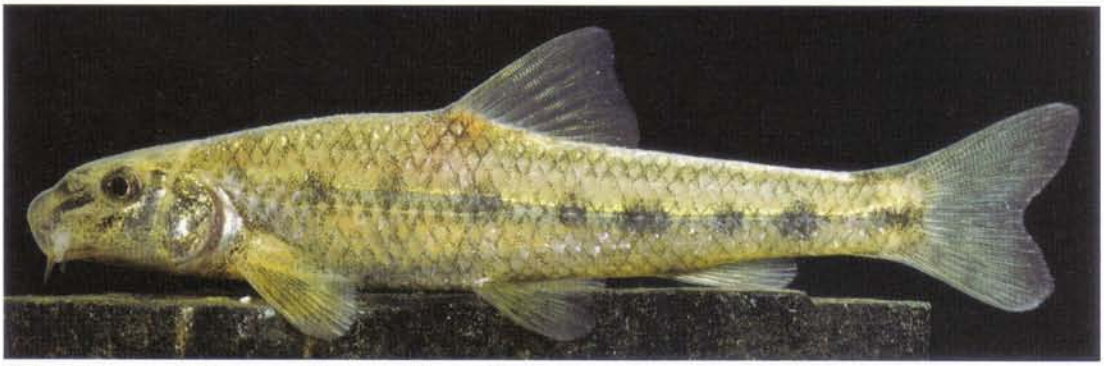

Gobio delyamurei; Chornaya, Ukraine; ~80 mm SL.

scales along midline / O barbel reaching between middle of eye and posterior eye margin / O snout length 0.9–1.0 times in postorbital distance / O head length 25–28 % SL / O head depth at nape 15–17 % SL, at eye 44–50 % HL / O body depth 18–25 % SL / O head width 14–16 % SL, 56–63 % HL / O eye diameter 4–6 % SL, 2.7–3.4 times in head depth, 1.4–1.7 times in interorbital distance (at 70–110 mm SL) / O depth of caudal peduncle 31–39 % HL. Size up to about 120 mm SL.

Distribution. Tisza system, Danube drainage.

Habitat. A wide variety of habitats in small rivers and streams.

Biology. No data.

Conservation status. LC.

Remarks. Molecular data suggest that the upper Tisza and Mureş populations are distinct lineages.

Further reading. Vladykov, 1925: 248 (description); Jaszfalusi, 1951: 119 (description; as *G. g. muresia*).

Gobio delyamurei

Common name. Chornaya gudgeon.

Diagnosis. Distinguished from other species of *Gobio* in Black and Caspian Sea basins by: ● mature males with numerous dark grey pigments on belly / O breast scaled between pectorals, scales extending forward beyond pectoral base (at least in some individuals) / O snout length greater than postorbital distance / O 6–9 (usually 7–8) scales between anus and anal origin / O barbel reaching to or slightly in front of anterior eye margin, its length 13–22 % HL, 2.0–3.3 times in snout length / O head length 24–27 % SL / O head depth at nape 14–20 % SL, at eye 47–53 % HL / O body depth 20–23 % SL / O head width 14–17 % SL, 53–63 % HL / O eye diameter 5–6 % SL, 2.5–3.8 times in head depth, 1.2–1.6 times in interorbital distance (at 70–100 mm SL) / O depth of caudal peduncle 32–39 % HL. Size up to about 100 mm SL.

Distribution. Ukraine: Chornaya drainage (southern Crimea).

Habitat. A wide variety of habitats. Chornaya is a medium-sized stream with a flow of about 10 m^3/s. The inhabited stretch is about 25 km long. In its lower part, water is extracted in large quantities for irrigation and the stream is almost dry in summer.

Biology. No data.

Conservation status. CR B1ab(ii,iii) + 2ab(ii,iii). Still abundant in a very limited stretch of stream, but declining. If water abstraction intensifies, the whole steam might dry in summer.

Further reading. Freyhof & Naseka, 2005: 332 (description); Vasilieva et al., 2005: 737 (as *G. tauricus*); Kottelat & Bogutskaya, 2006 (nomenclature).

Gobio feraeensis

Common name. Thessaly gudgeon.

Diagnosis. Distinguished from other species of *Gobio* in Europe by: ● distance between anus and anal origin smaller than eye diameter / ● 3–4 scale

Gobio delyamurei

Gobio feraeensis

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Gobio feraeensis; Pinios (Thessaly), Greece; 70 mm SL.

Gobio gobio; Spree, Elbe drainage, Germany; 100 mm SL.

rows between anus and anal origin / ○ 36–38 + 2–3 lateral line scales / ○ 3½–4 scale rows between lateral line and pelvic origin / ○ breast scaled between pectorals / ○ 16 circumpeduncular scale rows / ○ eye diameter 1.0–1.3 times in interorbital distance. Size up to 100 mm SL.

Distribution. Greece: Thessaly: Pinios and Karla Lake drainages.

erate flow, usually sand bottom.

Biology. No data.

Conservation status. VU B1ab(i,ii,iii,iv,v). Small range, recently extirpated in Karla drainage.

Further reading. Stephanidis, 1973: 192 (description).

Gobio gobio

Gobio gobio

Common name. Gudgeon.

Diagnosis. Distinguished from other species of *Gobio* in Europe by: ○ 4–5 scales between anus and anal origin / ○ breast naked between pectorals / ○ usually 39–42 + 2 lateral line scales / ○ barbel reaching beyond anterior eye margin, usually to middle of eye / ○ snout length greater than postorbital distance / ○ head length 26–30 % SL / ○ eye diameter 5–7 % SL, 1.0–1.4 times in interorbital distance in individuals over about 60 mm SL (less in smaller ones), 2.4–2.8 times in head depth / ○ usually 12–14 circumpeduncular scale rows / ○ head depth at nape 15–17 % SL, at eye 43–51 % HL / ○ body depth 19–23 % SL / ○ head width 14–16 % SL, 49–57 % HL / ○ depth of caudal peduncle 30–34 % HL. Size up to 130 mm SL.

Distribution. Atlantic Ocean, North and Baltic Sea basins, from Loire drainage eastward, eastern Great Britain, Rhône and Volga drainages, upper Danube and middle and upper Dniestr and Dniepr drainages. In Finland, north to about 61°N. Introduced to eastern and northern Italy, Ireland, Wales and Scotland. Eastern and southern limits not clear.

Habitat. Nearly all types of riverine and lacustrine habitats with sand bottom. Known from small

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Gobio holurus; Samur, Russia; ~60 mm SL A. Naseka

mountain streams, large lowland rivers and large lakes. Spawns in shallow water, over stones, sand or plant material. Often at lake shores or in riffles.
Biology. Gregarious. Lives up to 5 years. Spawns for the first time at 1–3 years; most individuals spawn 1–2 years. Spawns several times in April – August at temperatures above 12°C. Eggs are released above substrate and drift with current, sinking to bottom and sticking to substrate. Larvae and juveniles are benthic and prefer detritus-rich sandy habitats and low current. Feeds on a wide variety of large benthic invertebrates.
Conservation status. LC.
Remarks. Usually considered to be a morphologically variable species, with different morphologies reflecting adaptations to different habitats, which is not demonstrated. The populations from the Caspian basin might be a distinct species.
Further reading. Bănărescu & Nalbant, 1973: 110 (systematics); Mann, 1980 (biology); Kottelat, 1997: 60 (systematics); Bănărescu et al., in Bănărescu, 1999: 81 (in part; includes data of several species); Kottelat & Persat, 2005: 213 (systematics).

Gobio holurus

Common name. Caspian gudgeon.
Diagnosis. Distinguished from other species of *Gobio* in Black and Caspian Sea basins by: ● pectoral reaching to or 1 scales in front of pelvic origin in mature males / ○ breast scaled between pectorals, scales extending forward beyond pectoral base (at least in some individuals of any population) / ○ barbel reaching to or beyond posterior eye margin / ○ head length 26–28 % SL / ○ head depth at nape 16–17 % SL, at eye 48–62 % HL / ○ body depth 22–23 % SL / ○ head width 15–17 % SL, 58–62 % HL / ○ eye diameter 4–6 % SL, 3.1–3.7 times in head depth, 1.4–1.5 times in interorbital distance (at 50–60 mm SL) / ○ depth of caudal peduncle 33–36 % HL. Size up to about 100 mm SL.
Distribution. Russia: Kuma, Terek and Sulak drainages in Western Caspian basin.
Habitat. A wide variety of habitats in small rivers and streams.
Biology. No data.
Conservation status. LC.
Further reading. Berg, 1949: 648 (description).

Gobio kovatschevi

Common name. Varna gudgeon.
Diagnosis. Distinguished from other species of *Gobio* in Black and Caspian Sea basins by: ○ breast scaled between pectorals, scales extending forward beyond pectoral base (at least in some individuals of any population) / ○ snout length greater than postorbital distance / ○ barbel reaching behind centre of eye, its length 25–34 % HL, 1.2–1.8 times in snout length / ○ head length 26–28 % SL / ○ head depth at nape 12–17 % SL, at eye 48–54 % HL / ○ body depth 22–25 % SL / ○ head width 16–18 % SL, 60–69 % HL / ○ eye diameter 5–6 % SL, 2.7–3.4 times in head depth,

Gobio holurus

Gobio kovatschevi

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Gobio kovatschevi; Provadiskaya, Bulgaria; ~95 mm SL.

Gobio krymensis; Salgir, Crimea, Ukraine; ~90 mm SL.

1.4–1.7 times in interorbital distance (at 70–100 mm SL) / ♦ depth of caudal peduncle 34–42 % HL. Size up to about 100 mm SL.

Distribution. Bulgaria: River Provadiskaya (enters Black Sea near Varna).

Habitat. Restricted to the upper and middle stretch of a small, slowly flowing stream.

Biology. No data.

Conservation status. VU B1ab(iii,v). Still locally abundant in upper reaches of Provadiskaya drainage, extirpated in lower reaches. Sharply declined due to pollution, decline expected to continue with ongoing economic development.

Further reading. Chichkoff, 1937: 257 (description).

Gobio krymensis

Gobio krymensis

Common name. Salgir gudgeon.

Diagnosis. Distinguished from other species of *Gobio* in Black and Caspian Sea basins by: ♦ breast scaled between pectorals, scales extending forward beyond pectoral base (at least in some individuals of any population) / ♦ snout length greater than postorbital distance / ♦ 4–8 (usually 5–6) scales between anus and anal origin / ♦ barbel reaching beyond anterior eye margin, often to middle of eye, its length 19–27 % HL, 1.6–2.3 times in snout length / ♦ head length 25–28 % SL / ♦ head depth at nape 14–17 % SL, at eye 47–50 % HL / ♦ body depth 17–25 % SL / ♦ head width 15–16 % SL, 46–61 % HL / ♦ eye diameter 5–6 % SL, 2.7–3.4 times in head depth, 1.4–1.7 times in interorbital distance (at 70–100 mm SL) / ♦ depth of caudal peduncle 32–40 % HL. Size up to about 110 mm SL.

Distribution. Ukraine: Salgir, Alma and Bel Bek drainages (southern Crimea).

Habitat. A wide variety of habitats in small rivers and streams.

Biology. No data.

Conservation status. VU B1ab(ii,iii,v). Still abundant in streams Bel Bek and Salgir as long as water is present. Already very rare in Alma drainage

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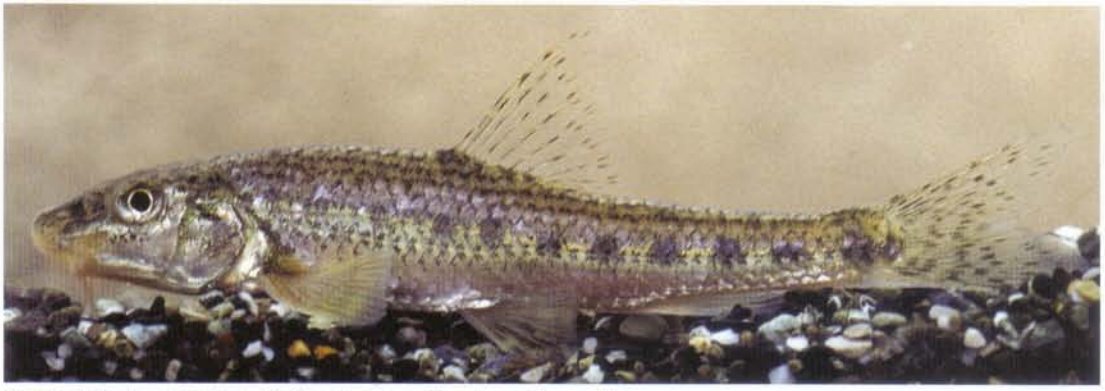


Gobio kubanicus; Belaya, Kuban drainage, Russia; ~65 mm SL.

due to water abstraction for irrigation. Decline will continue if water abstraction increases.

Remarks. The population from stream Kacha (Crimea) might be a distinct species. Superficially very similar to *G. kovatschevi*, but molecular characters show them to be very distinct.

Further reading. Berg, 1949: 650 (description); Bănărescu & Nalbant, 1973:119 (systematics).

Gobio kubanicus

Common name. Kuban gudgeon.

Diagnosis. Distinguished from other species of *Gobio* in Black and Caspian Sea basins by: O breast scaled between pectorals (at least in some individuals of any population) / O barbel reaching beyond posterior eye margin / O pectoral reaching 3–4 scales in front of pelvic origin in mature males / O head length 24–25 % SL / O head depth at nape 16–17 % SL, at eye 50–52 % HL / O body depth 21–22 % SL / O head width 15–16 % SL, 61–64 % HL / O eye diameter 4–5 % SL, 3.2–3.8 times in head depth, 1.4–1.8 times in interorbital distance (at 70–90 mm SL) / O depth of caudal peduncle 34–37 % HL. Size up to about 90 mm SL.

Distribution. Russia: Kuban drainage.

Habitat. A wide variety of habitats from montane rivers to small lowland streams with gravel or sand bottom.

Biology. No data.

Conservation status. LC.

Remarks. Populations from different tributaries show a great variability in shape, barbel length and squamation. Two groups of populations are recognized, the typical one (diagnosed above and in the key) with long barbels and a short-barbel one, which might represent an unnamed species. Alternatively, a hybrid zone between *G. brevicirris* and *G. kubanicus* cannot be ruled out.

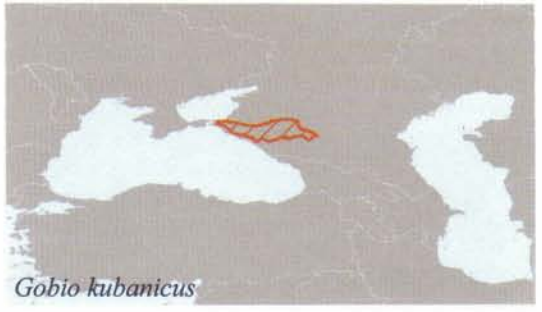
Further reading. Vasilieva et al., 2004 (description).

Gobio lozanoi

Common name. Iberian gudgeon.

Diagnosis. Distinguished from other species of *Gobio* in Europe by: O interorbital area flat to slightly convex / O 4–5 scales between anus and anal origin / O head length 25–28 % SL / O head depth 62–72 % HL / O breast scaled forward at most to posterior extremity of pectoral-fin base / O 36–37 + 2–3 lateral line scales / O 3–3½ scale rows between lateral line and pelvic origin / O usually 5½ scale rows between lateral line and dorsal origin / O eye diameter 1.2–1.8 times in interorbital distance / O depth of caudal peduncle 1.6–2.0 times in its length / O midlateral blotches contrasted, posterior ones with sharp margins / O 12–14 circumpeduncular scale rows. Size up to 120 mm SL.

Distribution. Spain: Ebro and Bidasoa drainag-



Gobio kubanicus

Gobio lozanoi

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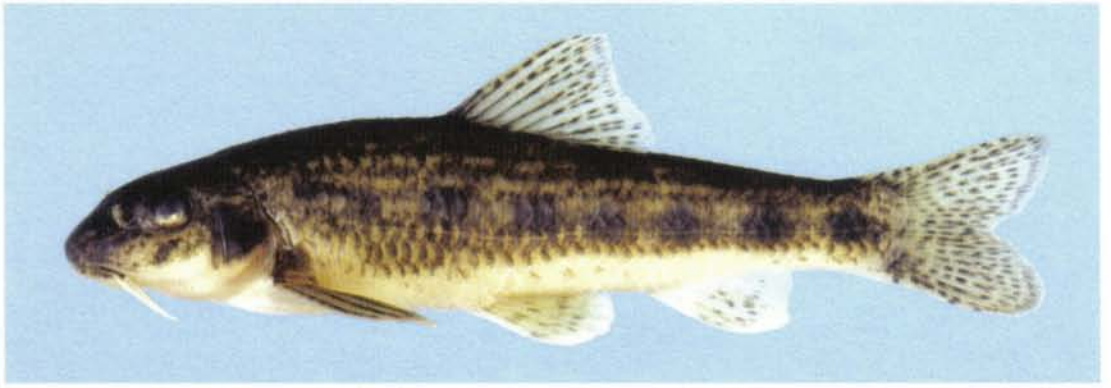

Gobio lozanoi; Adour, France; 98 mm SL.

Gobio obtusirostris; upper Save, Danube drainage, Slovenia; ~80 mm SL.

es; France: Adour drainage. Introduced to rest of Spain and Portugal.
Habitat. Streams in foot hills with moderate current, with sand or gravel bottom.
Biology. No data.
Conservation status. LC.
Further reading. Doadrio & Madeira, 2004: 109 (description); Kottelat & Persat, 2005: 220 (description).

Gobio obtusirostris

Common name. Danube gudgeon.
Diagnosis. Distinguished from other species of *Gobio* in Black and Caspian Sea basins by: ❍ interorbital area flat / ❍ breast naked between pectoral bases / ❍ barbel reaching between middle of eye and posterior eye margin / ❍ snout length 0.9–1.2 times in postorbital distance / ❍ head length 26–32 % SL / ❍ head depth at nape 16–18 % SL, at eye 46–53 % HL / ❍ body depth 22–25 % SL / ❍ head width 16–19 % SL, 59–69 % HL / ❍ eye diameter 5–6 % SL, 2.8–3.4 times in head depth, 1.3–1.8 times in interorbital distance (at 70–100 mm SL) / ❍ depth of caudal peduncle 36–44 % HL / ❍ midlateral blotches contrasted, with sharp edges / ❍ 12–14 circumpeduncular scale rows. Size up to 125 mm SL.
Distribution. Middle and upper Danube drainage.

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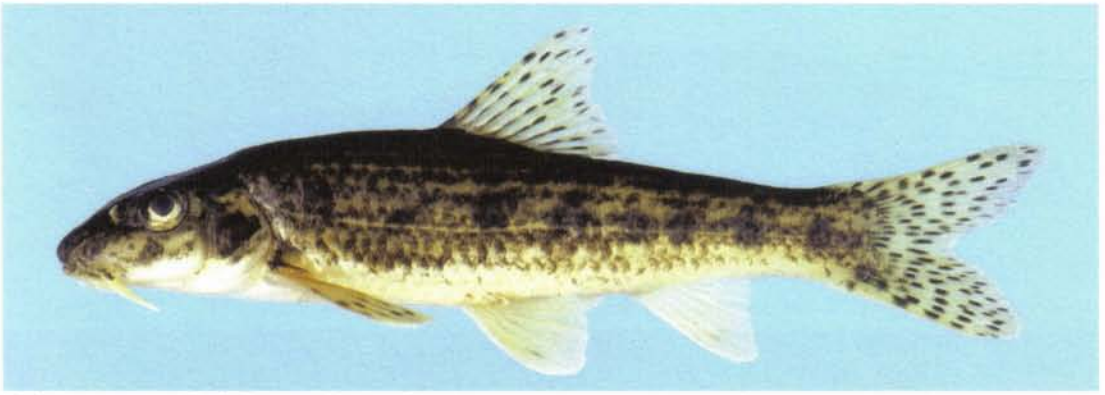


Gobio occitaniae; Tech, France; 82 mm SL.

Gobio ohridanus; Lake Ohrid, Macedonia; 89 mm SL.

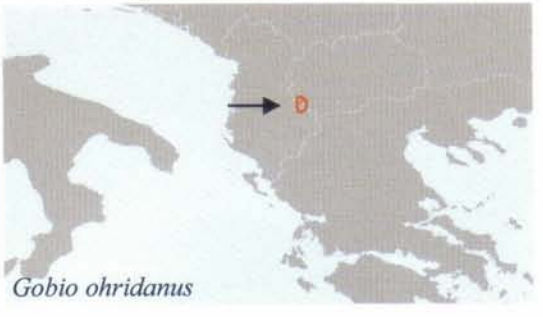
Habitat. Riverine and lacustrine habitats with sand bottom. Spawns in shallow water, over stones, sand or plant material.
Biology. No data.
Conservation status. LC.
Remarks. The distribution limits are not clear. The existence of a hybrid zone between *G. obtusirostris* and *G. gobio* in the upper Danube is suspected.
Further reading. Bănărescu, 1954 (morphology).

Gobio occitaniae

Common name. Languedoc gudgeon.
Diagnosis. Distinguished from other species of *Gobio* in Europe by: ○ interorbital area flat / ○ 5 scales between anus and anal origin / ○ head length 26–30 % SL / ○ breast scaled forward until in front of pectorals / ○ 37–39 + 2–3 lateral line scales / ○ 3½–4 scale rows between lateral line and pelvic origin / ○ eye diameter 1.2–1.7 times in interorbital distance / ○ depth of caudal peduncle 1.5–2.0 times in its length / ○ midlateral blotches not conspicuous, not contrasted and with fuzzy margins / ○ 12–16 (usually 14) circumpeduncular scale rows. Size up to 130 mm SL.
Distribution. France: Garonne drainage and streams draining to Mediterranean between Rhône and Pyrénées.
Habitat. Streams in hilly area with moderate current, over sand bottom.
Biology. No data.
Conservation status. LC.
Further reading. Kottelat & Persat, 2005: 224 (description).

Gobio ohridanus

Common name. Ohrid gudgeon.
Diagnosis. Distinguished from other species of *Gobio* in Europe by: ● head length 29–34 % SL / ○ 4–5 scales between anus and anal origin / ○ breast naked between pectorals / ○ 36–39 + 2–3 lateral line scales / ○ eye diameter 1.1–1.5 times in interorbital distance / ○ snout length 40–45 % HL / ○ interorbital area markedly concave in individuals larger than about 70 mm SL / ○ 7–10



Gobio ohridanus

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Gobio sarmaticus; lower Dniestr, Ukraine; 103 mm SL.

Gobio skadarensis; Moraca, Drin drainage, Montenegro; ~55 mm SL.

midlateral blotches, irregularly set and shaped / ○ several irregularly-set black blotches on back, slightly smaller than blotches of midlateral row / ○ a row of black subdistal spots on dorsal rays. Size up to 130 mm SL.

Distribution. Lake Ohrid (Macedonia, Albania). Imported in France and probably other countries, might be locally established.

Habitat. Lacustrine, usually on sand to pebble bottom.

Biology. Gregarious. Spawns in June – July.

Conservation status. VU D2.

Further reading. Bănărescu & Nalbant, 1973: 117 (systematics); Grupče & Dimovski, 1975 (morphology).

Gobio sarmaticus

Common name. Ukrainian gudgeon.

Diagnosis. Distinguished from other species of *Gobio* in Black and Caspian Sea basins by: ○ breast naked between pectorals or scales only along midline / ○ barbel reaching between anterior eye margin and middle of eye / ○ snout length 0.8–0.9 times in postorbital distance / ○ head length 26–32 % SL / ○ head depth at nape 17–18 % SL, at eye 45–54 % HL / ○ body depth 21–24 % SL / ○ head width 16–19 % SL, 54–61 % HL / ○ eye diameter 5–7 % SL, 2.8–3.5 times in head depth, 1.3–1.8 times in interorbital distance (at 70–100 mm SL) / ○ depth of caudal peduncle 29–34 % HL. Size up to about 130 mm SL.

Distribution. Ukraine: lower parts of Dniestr and South Bug drainages. Likely to occur as well in

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Pseudorasbora parva; Kacka, Ukraine; female, ~60 mm SL (above) and male, ~80 mm SL (below).

lower Dniepr.
Habitat. Streams in foot hills and lowlands with moderate current.
Biology. No data.
Conservation status. LC.
Further reading. Berg, 1949: 643 (description).

Gobio skadarensis

Common name. Skadar gudgeon.
Diagnosis. Distinguished from other species of *Gobio* in Adriatic and Aegean Sea basins by: O head length 27–30 % SL / O breast naked between pectorals, scales not reaching forward beyond pectoral base / O 37–38 + 3 lateral line scales / O barbel reaching to or beyond posterior eye margin / O eye diameter 1.2–1.4 in interorbital distance / O snout length 34–42 % HL / O 6–7 midlateral blotches, often grouped two by two. Size up to about 90 mm SL.
Distribution. Montenegro, Albania: Lake Skadar basin.
Habitat. Lake Skadar and lower parts of tributary streams.
Biology. No data.
Conservation status. EN B1ab(ii,iii) + 2ab(ii,iii).
Further reading. Bănărescu & Nalbant, 1973: 117 (systematics).

Pseudorasbora parva

Common name. Pseudorasbora.
Diagnosis. Only species of genus in Europe. Distinguished from other species of Cyprinidae in Europe by: O mouth small, superior / O barbels absent / O dark midlateral stripe outside spawning time / O lateral line usually complete / O 33–38 total lateral line scales / O 7½ branched dorsal rays / O 6½ branched anal rays / O no dorsal or ventral keels. Size up to 95 mm SL.
Distribution. Native from Amur to Zhujiang [Pearl River] drainages (Siberia, Korea, China). Introduced to Romania in 1961 with fry of *Ctenopharyngodon idella* from middle Changjiang [Yangtze] and to Russia and Ukraine from Amur (see also under *Hypophthalmichthys*), from where it colonised most of Europe, either by active invasion, as stocked or released bait, or accidentally mixed with fingerlings of other species. Now widespread especially in eastern Europe (Danube to Kuban drainages, east to Volga and south to central Iran), but still spreading in central, western and southern Europe, having reached France (Seine, Rhône, Loire), the Netherlands, Denmark, England, Italy (south to Ombrone), Spain, Greece, Turkey and Algeria.
Habitat. Ubiquitous, in a wide variety of habitats. Most abundant in well vegetated small channels, ponds and small lakes. Usually spawns in habitats with still or very slow-flowing water.

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Biology. Lives up to 3 years. Spawns for the first time at 1 year. Males larger than females, with much deeper body and darker and brighter coloration. Males show bluish grey breeding coloration and few, very large nuptial tubercles on snout. Spawns in March – June. Females usually spawn 3–4 times during a season. Males clear the surface of a spawning site as stones or plants. Eggs are attached to the substrate and are guarded by males until emergence of larvae. Feeds on a wide variety of small crustaceans, insects and even plant material.
Conservation status. Alien. Usually not abundant in flowing waters. Locally proliferates in ponds and other artificial habitats, becomes very quickly numerically dominant and a serious food competitor for native species.
Further reading. Bănărescu, 1999: 207 (biology); Britton et al., 2006 (impact).

Key to species of *Romanogobio* in Europe

Several species of *Romanogobio* have longitudinal epithelial crests on predorsal scales (Fig. 28). These are soft structures on the scale surface and they are easily lost in case of poor fixation or damaged during transportation. Species of the *R. albipinnatus* group are morphologically very similar but molecular data confirm they are distinct. These species are allopatric and their geographic origin is a good starting point for identification.

1a – 5½ branched anal rays (Kuban drainage, invasive in Don).
..... *R. pentatrichus*
1b – 6½ branched anal rays.
..... 2

2a – Anus closer to anal origin than to pelvic origin (North Adriatic basin).
..... *R. benacensis*
2b – Anus midway between pelvic and anal origins or closer to pelvic origin.
..... 3

3a – No longitudinal epithelial crests on predorsal scales (Danube basin).
..... *R. uranoscopus*
3b – Longitudinal epithelial crests on predorsal scales present (Fig. 28).
..... 4

4a – 8½ branched dorsal rays.
..... 5
4b – 7½ branched dorsal rays.
..... 6

5a – 4 scales between lateral line and pelvic origin; eye very small, diameter 17–23 % HL (lower Danube).
..... *R. antipai*
5b – 3 scales between lateral line and pelvic origin; eye large, diameter 20–28 % HL (Dniestr, Danube and Vistula drainages).
..... *R. kesslerii*

6a – Eye diameter 1.5–2.6 times in interorbital distance (West Caspian basin).
..... *R. ciscaucasicus*
6b – Eye diameter 0.7–1.5 times in interorbital distance.
..... 7

7a – Longitudinal epithelial crests on predorsal scales on posterior scale margin only (Vardar to Pinios drainages).
..... *R. elimeius*
7b – Longitudinal epithelial crests on predorsal scales on whole exposed part of scale.
..... 8

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Romanogobio albipinnatus; upper Volga drainage, Russia; 83 mm SL.

8a – 10–12 circumpeduncular scales rows (Kuban drainage).
..... *R. parvus*

8b – 14–16 circumpeduncular scales rows.
..... 9

9a – 42–43 + 2 lateral line scales; eye diameter usually less than interorbital distance (Caspian basin).
..... *R. albipinnatus*

9b – 39–42 + 2 lateral line scales; if 42 + 2 lateral lines scales, eye diameter usually equal to or greater than interorbital distance.
..... 10

10a – Dorsal fin in middle of body, predorsal length equal to postdorsal length (Don drainage).
..... *R. tanaiticus*

10b – Dorsal fin behind middle of body, predorsal length greater than postdorsal length.
..... 11

11a – Anus closer to pelvic origin than to anal origin (Baltic and North Sea basins; Dniestr, South Bug and Dniepr drainages).
..... *R. belingi*

11b – Anus midway between pelvic and anal origins or slightly closer to anal origin than to pelvic origin (Danube drainage).
..... *R. vladykovi*

Romanogobio albipinnatus

Common name. Volga whitefin gudgeon.

Diagnosis. Distinguished from other species of *Romanogobio* in Caspian Sea basin by: ○ longitudinal epithelial crests on predorsal scales (Fig. 28) / ○ 14–16 circumpeduncular scale rows / ○ 42–43 + 2 lateral line scales / ○ 7½ branched dorsal rays / ○ 6½ branched anal rays. Size up to 115 mm SL.

Distribution. Northern Caspian basin (Volga, Ural).

Habitat. Bottom of moderately flowing lowland rivers, prefers sand bottom.

Biology. Lives up to 5 years. Spawns for the first time at 2 years. Females spawn up to 4 times during a season at about two-week intervals in May – July. Nocturnal benthic, feeds on insect larvae and other larger benthic invertebrates.

Conservation status. LC. Locally threatened by pollution and river engineering.

Further reading. Naseka et al., in Bănărescu, 1999: 37 (biology); Naseka, 2001: 103 (description).

Romanogobio antipai

Common name. Danube delta gudgeon.

Diagnosis. Distinguished from other species of *Rhomanogobio* in Black Sea basin by: ● eye very small, diameter 17–23 % HL / ○ longitudinal epithelial crests on predorsal scales (Fig. 28) / ○ 12

Romanogobio albipinnatus

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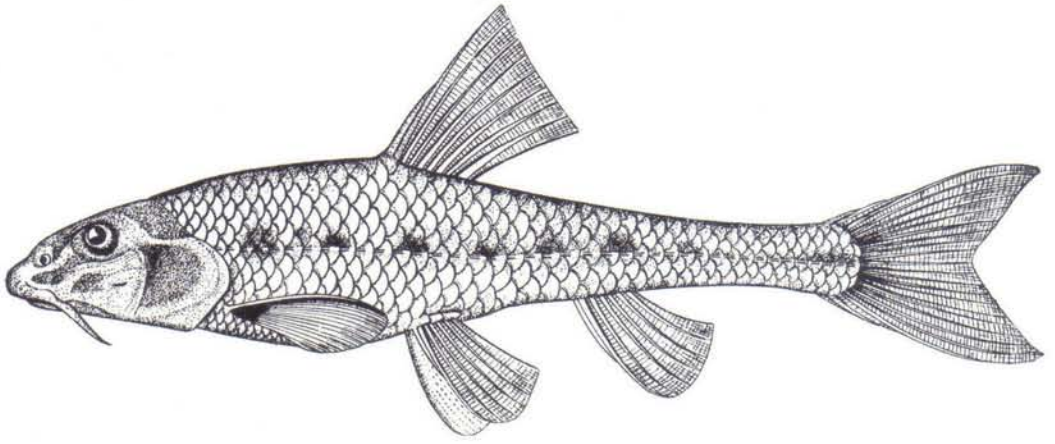

Romanogobio antipai; Danube delta, Romania; 68 mm SL. (from Bănărescu, 1964)

circumpeduncular scale rows / O 8½ branched dorsal rays / O 6½ branched anal rays / O 4 scale rows between lateral line and pelvic origin. Size up to 71 mm SL.

Distribution. Lower Danube in Romania and Ukraine, from confluence with River Arges downstream to delta.

Habitat. Deep waters of large rivers on sand bottom.

Biology. No data.

Conservation status. Extinct.

Remarks. Earlier considered to be a subspecies of *R. kessleri*.

Further reading. Bănărescu & Nalbant, 1973: 157 (systematics); Bănărescu, 1992 (systematics), 1994a (systematics), 1999: 135 (biology); Kottelat, 1997: 62 (systematics).

Romanogobio belingi

Common name. Northern whitefin gudgeon.

Diagnosis. Distinguished from other species of *Romanogobio* in Baltic and Black Sea basins by: O longitudinal epithelial crests on predorsal scales (Fig. 28) / O 14–16, rarely 12 circumpeduncular scale rows / O 7½ branched dorsal rays / O 6½ branched anal rays / O 39–42 + 2 lateral line scales / O dorsal behind middle of body, predorsal length greater than postdorsal length / O anus closer to pelvic origin than to anal origin / O snout longer than or equal to postorbital distance. Size up to 115 mm SL.

Romanogobio antipai

Distribution. Northern Black Sea basin (Dniestr, South Bug and Dniepr drainages), southern Baltic basin (Odra, Vistula), southern North Sea basin (Elbe, Rhine). Occurrence in Lake Ilmen and Ladoga basins questionable.

Habitat. Bottom of moderately flowing lowland rivers, prefers sand bottom.

Biology. Lives up to 5 years. Spawns for the first time at 2 years. Females spawn up to 4 times during a season at about two-week intervals in May – July. To spawn, both sexes move to surface or open water. Nocturnal, benthic, feeds on insect larvae and other larger benthic invertebrates.

Conservation status. LC. Most likely declined because of construction of large reservoirs on rivers Dniestr, Dniepr and Odra in 20th century. Suspected to have stabilised at a moderate level, very abundant in free flowing parts of rivers. Populations in Germany have recovered; populations in Poland are expected to recover in next decades.

Remarks. Earlier considered to be a subspecies of *R. albipinnatus*.

Further reading. Naseka et al., in Bănărescu, 1999: 37 (biology); Naseka, 2001: 103 (description).

Romanogobio benacensis

Common name. Italian gudgeon.

Diagnosis. Distinguished from other species of *Romanogobio* in Europe by: ● 2–3 scales between anus and anal origin / O scales on belly extending forward to a point between pectoral and pelvic

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Romanogobio belingi; Odra, Germany; ~95 mm SL.

Romanogobio benacensis; Lake Garda, Italy; ~65 mm SL.

bases / ○ no longitudinal epithelial crests on predorsal scales. Size up to 100 mm SL.

Distribution. Italy and Slovenia: from Po to Soca and Reka drainages. Possibly present elsewhere in northern Adriatic basin. Introduced to central and southern Italy.

Habitat. A wide variety of habitats as large lowland rivers, canals, warm streams and lakes. Usually on sand bottom. Avoids very fast waters.

Biology. Lives about 4 years. Spawns for the first time at 1–2 years, usually spawns one or two years. Spawns in April – June, in several portions, on sand bottom. Eggs hatch in 7–8 days. Feeds on a variety of small invertebrates. Lives in small groups.

Conservation status. EN B2ab(i,ii,iii,iv,v), due to pollution, river-bed alterations and competition from introduced *Gobio gobio*. Now restricted to a very few populations.

Further reading. Bruno, 1987 (biology); Bănărescu et al., in Bănărescu, 1999: 110 (morphology); Bianco & Taraborelli, 1984: 526 (systematics); Gandolfi et al., 1991: 192 (biology).

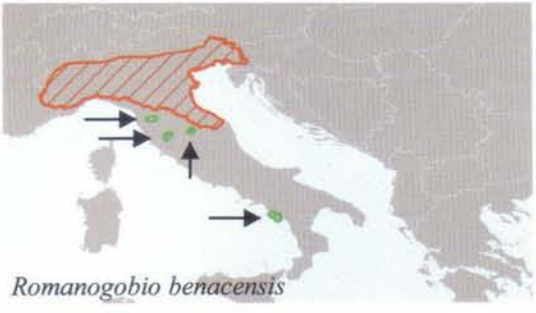
Romanogobio ciscaucasicus

Common name. Caucasian gudgeon.

Diagnosis. Distinguished from other species of *Romanogobio* in Black and Caspian Sea basins by: ● eye diameter 1.5–2.6 times in interorbital distance / ○ longitudinal epithelial crests on predorsal scales (Fig. 28) / ○ 12–16 circumpeduncular scale rows / ○ 7½ branched dorsal rays / ○ anus closer to pelvic origin than to anal origin / ○ 6½ branched anal rays / ○ greatest head width 59–72 % of dorsal head length. Size up to 110 mm SL.

Distribution. Western Caspian basin: from Kuma (Russia) to Yalaminskie (Azerbaijan) drainages.

Romanogobio belingi



Romanogobio benacensis

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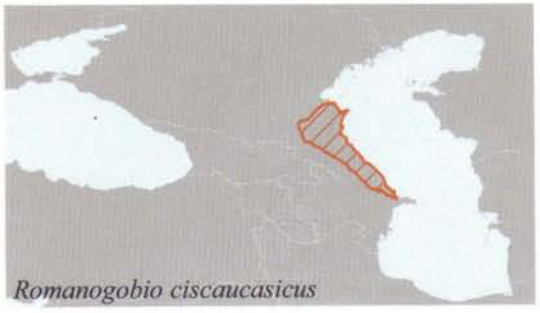
Romanogobio ciscaucasicus; Terek, Russia; ~65 mm SL. A. Naseka

Romanogobio elimeius; Vardar, Greece; 56 mm SL.

Habitat. Inhabit streams and river stretches with fast current and gravel bottom.
Biology. Almost no data. Lives up to 6 years. Feeds on Trichoptera larvae.
Conservation status. LC.
Further reading. Naseka & Bogutakaya, in Bănărescu, 1999: 226 (description).

Romanogobio elimeius

Common name. Greek stone gudgeon.
Diagnosis. Only species of genus in Aegean drainage. Distinguished from species of *Romanogobio* in Black Sea basin by: ○ 7½ branched dorsal rays / ○ 6½ branched anal rays / ○ anus midway between pelvic and anal origins / ○ absence of scales between pectoral bases / ○ longitudinal epithelial crests on predorsal scales restricted to posterior scale margin. Size up to about 100 mm SL.
Distribution. From Vardar to Pinios drainages (Greece, Macedonia).
Habitat. Main course of large rivers and main tributaries, in relatively deep water, with sand bottom and near riffles.
Biology. Spawns in May – June, sometimes as late as August.
Remarks. We are not able to distinguish *R. banarescui* and *R. stankoi* from *R. elimeius* on the basis of the available literature and material and therefore tentatively treat them as synonyms.
Conservation status. LC. Most likely threatened by pollution and river-bed alterations.
Further reading. Kattoulas et al., 1973: 179 (description); Dimovski & Grupče, 1974a: 83 (description; as *Gobio kessleri banarescui*), 1976 (description, as *G. uranoscopus stankoi*).



Romanogobio ciscaucasicus

Romanogobio elimeius

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Romanogobio kesslerii; Kolpa, Danube drainage, Slovenia; ~100 mm SL.

Romanogobio kesslerii

Common name. Sand gudgeon.

Diagnosis. Distinguished from other species of *Romanogobio* in Baltic and Black Sea basins by: ○ longitudinal epithelial crests on predorsal scales (Fig. 28) / ○ 12 circumpeduncular scale rows / ○ 8½ branched dorsal rays / ○ 6½ branched anal rays / ○ 3 scale rows between lateral line and pelvic origin / ○ eye small, diameter 20–28 % HL, 1.0–1.3 times in interorbital distance / ○ body depth 14–21 % SL. Size up to 110 mm SL.

Distribution. Dniestr and tributaries of lower and middle Danube drainages (Black Sea basin); upper Vistula drainage in Poland (Baltic basin).

Habitat. Fast-flowing piedmont rivers with large areas of sand bottom. Spawns in shallow water over gravel, sand or plant material in fast-flowing water.

Biology. Gregarious. Lives up to 5 years. Spawns for the first time at 2–3 years. Most fish spawn 1–2 years, in late May – September. Eggs are released in successive portions. To spawn, both sexes move to surface or open water. Eggs drift with current, sink to bottom and stick to substrate. Juveniles and adults are active during day. Feeds on a variety of benthic invertebrates, usually catching drifting preys.

Conservation status. LC. Expected to gradually decline with on-going economic development. Sensitive to organic pollution. Locally threatened.

Remarks. The systematics of sand gudgeons in Danube is not resolved and several species seem to be confused under the name *R. kesslerii*.

Further reading. Bănărescu & Nalbant, 1973: 157 (systematics); Bănărescu, 1992 (systematics), 1994a (systematics); Bănărescu, 1999: 135 (biology); Kottelat, 1997: 62 (systematics).

Romanogobio parvus

Common name. Small Kuban gudgeon.

Diagnosis. Distinguished from other species of *Romanogobio* in Black and Caspian Sea basins by: ○ longitudinal epithelial crests on predorsal scales (Fig. 28) / ○ 10–12 circumpeduncular scale rows / ○ 7½ branched dorsal rays / ○ 6½ branched anal rays / ○ eye diameter 1.0–1.4 times in interorbital distance / ○ dorsal fin behind middle of body, postdorsal length 87–97% of predorsal length / ○ anus midway between pelvic and anal origins / ○ snout shorter or equal to postorbital distance / ○ greatest head width 52–59 % of dorsal head length. Size up to 75 mm SL.

Distribution. Black Sea basin: Kuban drainage.

Habitat. Restricted to large, high-gradient river stretches with fast but not turbulent current and gravel or sand bottom.

Biology. Almost no data. Nocturnal, at night near shores on mud or sand bottom. Seems to spawn late and to have a long spawning period. Many small juveniles found in July. Feeds on benthic invertebrates, mainly Trichoptera larvae.

Conservation status. LC. Abundant in middle Kuban, but very restricted range. Decline suspect-

Romanogobio kesslerii

Romanogobio parvus

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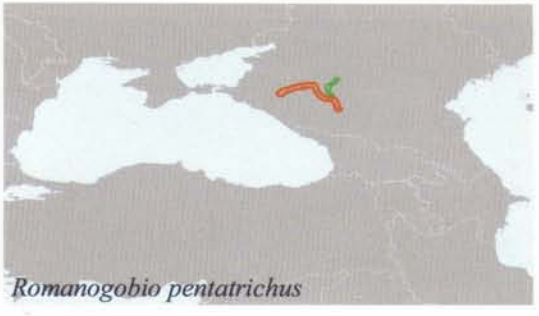
Romanogobio parvus; Kuban, Russia; ~55 mm SL.

Romanogobio pentatrichus; Kuban, Russia; 95 mm SL.

ed and expected gradually to continue with ongoing economic development.
Further reading. Naseka & Freyhof, 2004: 18 (description).

Romanogobio pentatrichus

Common name. Five-rayed gudgeon.
Diagnosis. Distinguished from other species of *Romanogobio* in Europe by: ● 5½ branched anal rays / ○ no longitudinal epithelial crests on predorsal scales. Size up to 130 mm SL.
Distribution. Middle stretches of River Kuban (Russia). Invasive in Don drainage, in River Egorlyk, which it entered through Nevinnomyssky canal.
Habitat. High-gradient stretches of large rivers with fast (not turbulent) current and gravel or sand bottom.



Romanogobio pentatrichus

Biology. Nocturnal, found near shores during night on mud or sand bottom. Seems to spawn early and have a short spawning period. Only large juveniles observed in July.
Conservation status. LC. Abundant in middle Kuban, but in a very restricted range. Decline suspected and expected gradually to continue with ongoing economic development.
Further reading. Naseka & Bogutskaya, 1998: 174 (description).

Romanogobio tanaiticus

Common name. Don whitefin gudgeon.
Diagnosis. Distinguished from other species of *Romanogobio* in Black Sea basin by: ● dorsal fin in middle of body, predorsal length equal to postdorsal length / ○ longitudinal epithelial crests on predorsal scales (Fig. 28) / ○ 14–16 circumpeduncular scale rows / ○ 39–42 + 2 lateral line scales / ○ 7½ branched dorsal rays / ○ 6½ branched anal rays snout / ○ snout shorter than or equal to postorbital distance. Size up to 100 mm SL.
Distribution. Don drainage.
Habitat. Bottom of moderately flowing lowland rivers, prefers sand bottom.
Biology. Lives up to 5 years. Spawns for the first time at 2 years. Females spawn up to 4 times during a season at about two-week intervals in May – July. Nocturnal, benthic, feeds on insect larvae and other large benthic invertebrates.

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Romanogobio tanaiticus; lower Don, Russia; ~60 mm SL. A. Naseka

Romanogobio uranoscopus; Nera, Danube drainage, Romania; ~80 mm SL.

Conservation status. LC. Locally threatened by pollution and river engineering. Most likely declined due to construction of large reservoirs on Don in 20th century. Suspected to have stabilised at a moderate level in recent times.

Remarks. Earlier considered to be a subspecies of *R. albipinnatus*.

Further reading. Naseka et al., in Bănărescu, 1999: 37 (biology); Naseka, 2001: 103 (description).

Romanogobio uranoscopus

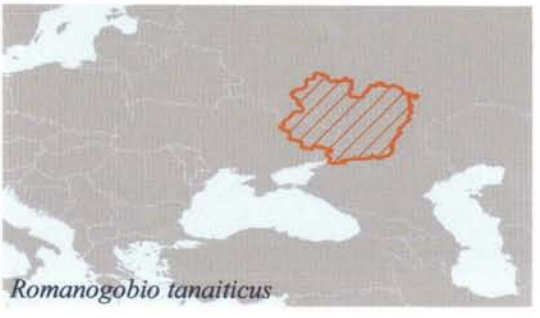
Common name. Stone gudgeon.

Diagnosis. Distinguished from other species of *Romanogobio* in Black Sea basin by: ❍ anus midway between pelvic and anal origins or closer to anal origin / ❍ no longitudinal epithelial crests on predorsal scales / ❍ depth of caudal peduncle 3.0–3.5 times in its length / ❍ dorsal and caudal rays with faint dark spots, forming one dark vertical row. Size up to 100 mm SL.

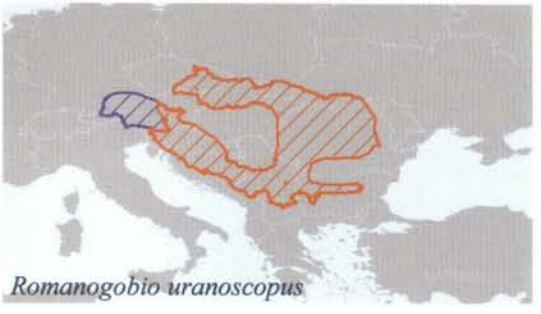
Distribution. Danube drainage (absent from Danube main river except upper course and stretches with fast current).

Habitat. Riffles of small, fast-flowing rivers and bottom of large rivers with water velocities of 0.7 m/s and more, stone bottom, in submontane zone. Young individuals prefer slow current and shallow shoreline habitats with sand bottom. Spawns in shallow habitats with very high current (about 1 m/s).

Biology. In laboratory, spawns several times between late May and mid-September, at temperatures above 11°C. Males wait for females at spawning sites. To spawn, both sexes move to surface or open water. Eggs drift with current, sink to bottom and then stick to substrate. Adults are nocturnal and solitary, juveniles are active at day. No data



Romanogobio tanaiticus



Romanogobio uranoscopus

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Romanogobio vladykovi; middle Danube drainage, Hungary; ~65 mm SL. Z. Sallai

on food in the wild.

Conservation status. LC. Still frequent in suitable habitats. Declined and expected to continue declining with on-going economic development. Sensitive to pollution and damming. Locally threatened especially in western and southern Danube drainage, extirpated in upper Danube.

Further reading. Bănărescu & Nalbant, 1973: 138 (systematics); Bănărescu et al., in Bănărescu, 1999: 183 (biology), Kottelat, 1997: 62 (systematics).

Romanogobio vladykovi

Common name. Danube whitefin gudgeon.

Diagnosis. Distinguished from other species of *Romanogobio* in Black Sea basin by: ○ longitudinal epithelial crests on predorsal scales (Fig. 28)) / ○ 14–16 circumpeduncular scale rows / ○ 37–41 + 2 lateral line scales / ○ 7½ branched dorsal rays / ○ 6½ branched anal rays / ○ dorsal behind middle of body, predorsal length greater than postdorsal length / ○ anus midway between pelvic and anal origins or slightly closer to anal origin than to pelvic origin / ○ snout shorter than or equal to postorbital distance. Size up to 115 mm SL.

Distribution. Danube drainage.

Habitat. Bottom of moderately flowing large and medium size lowland rivers; prefers sand bottom. Juveniles may inhabit backwaters. Lacustrine population in Lake Balaton (Hungary).

Biology. Lives up to 4 years. Spawns for the first time at 2 years. Females spawn up to 4 times during a season at about two-week intervals in May – July. Nocturnal, benthic, feeds on insect larvae and other large benthic invertebrates.

Conservation status. LC. Most likely declined due construction of large reservoirs on Danube in 20th century. Stabilised at a moderate level since. Abundant in free-flowing parts of middle and lower Danube.

Remarks. Earlier treated as a subspecies of *R. albipinnatus*.

Further reading. Naseka et al., in Bănărescu, 1999: 37 (biology); Naseka, 2001: 103 (description).

Romanogobio vladykovi

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Subfamily Cyprininae

Carps, barbels

Cyprininae are the largest subfamily within the family Cyprinidae. The European species are distinguished by having two pairs of barbels (except *Carassius* species) and 8½ or 14–21½ branched dorsal rays. There are only 38 species of Cyprininae native to European waters. The subfamily is most diverse in Africa and east, southeast and south Asia where some species reportedly grow up to about 2 m; at the other extreme, some species hardly reach 20 mm SL. They inhabit a variety of habitats from hill streams to lakes, estuaries and caves.

In Cyprinidae, the different structures around the mouth are important to diagnose genera. They include the rostral cap, the upper and lower lips, the upper and lower jaws, and the barbels (Fig. 30). They are variously developed or may be missing in the different genera. The *rostral cap* is the fleshy tissue at the tip of the snout. It is separated from the *upper lip* by the *rostral groove*; in several genera, the rostral cap is developed into a pendulous fold partly or totally covering the upper lip and the upper jaw. In such cases, the upper lip may be missing. The *lower lip* is separated from the skin of the throat by a *postlabial groove*. This groove is usually interrupted in the middle. In some species with fleshy lips the median part may be hypertrophied and folded backward into a pendulous lobe. The *lower jaw* may be covered by a keratinous tissue with a cutting anterior edge. In such cases, the lower jaw is often exposed and the lower lip restricted to the sides of the jaw.

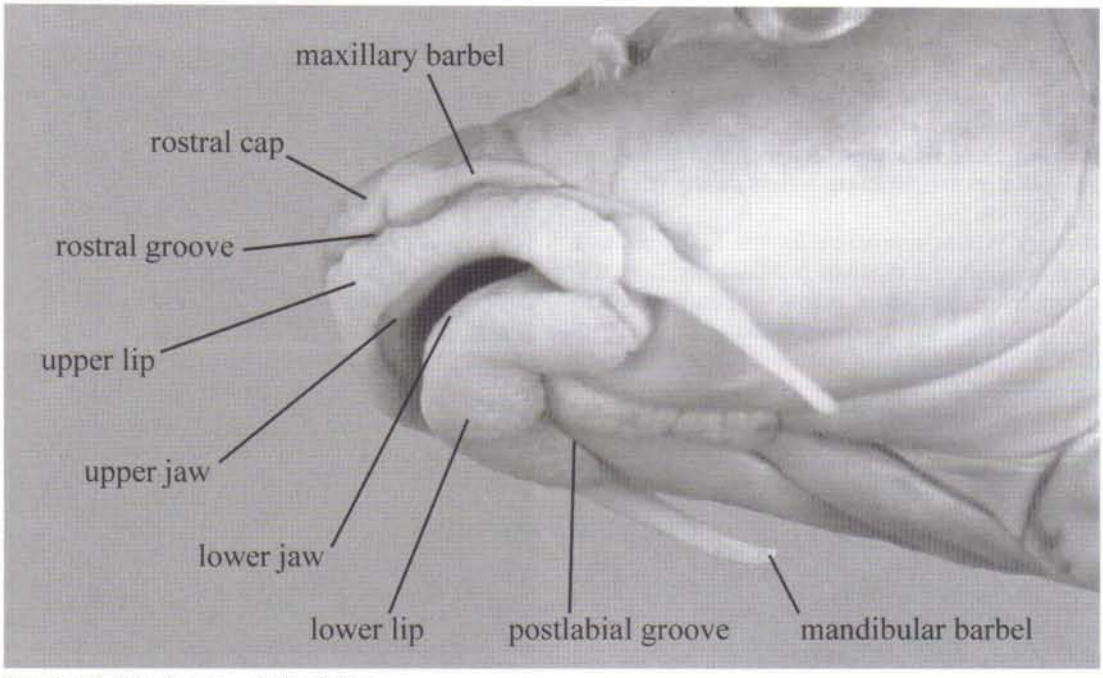

Figure 30 Mouth parts of Cyprinidae.

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Key to genera of Cyprininae in Europe

1a – 14–21½ branched dorsal rays; last simple anal rays spinous, hard and serrated posteriorly. 2

1b – 7–8½ branched dorsal rays; last simple anal ray neither spinous nor serrated posteriorly. 3

2a – No barbels. ..... *Carassius*

2b – Two pairs of barbels. ..... *Cyprinus*

3a – Scales almost or completely absent; prolonged urogenital papilla fused with anterior edge of anal in female. ..... *Aulopyge*

3b – Body completely covered with scales; urogenital papilla not fused with anal in female. 4

4a – Few and large nuptial tubercles on snout; in most species, lower lip thin, without median lobe or swollen pad. ..... *Luciobarbus*

4b – Numerous very small nuptial tubercles on head and anterior part of body; lower lip thick, with a median lobe or a swollen pad. ..... *Barbus*

Aulopyge huegelii

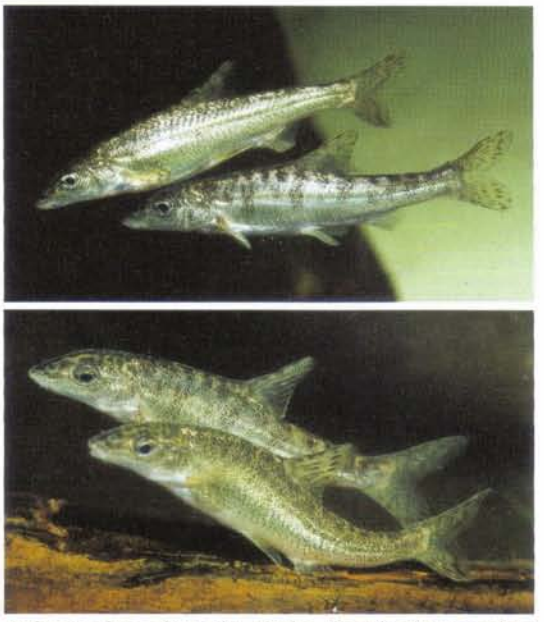
Common name. Oštrulj.

Diagnosis. Only species of genus. Distinguished from other species of Cyprinidae in Europe by: ● prolonged urogenital papilla fused with anterior edge of anal in female / ○ two pairs of barbels / ○ last simple dorsal ray serrated / ○ scales almost or completely absent. Size up to about 200 mm SL.

Distribution. Karstic streams in Glamočko, Livanjsko and Duvanjsko poljes, Lakes Buško and Blidinje (Bosnia-Herzegovina); Cetina, Krka and Zrmanja drainages (Croatia).

Habitat. Streams with swift water, still waters and lakes. Enters subterranean waters during winter or dry periods.

Biology. Males reproduce for the first time at 1 year, females at 2. Spawns in May in shallow water of rivers and lakes, when temperatures reach 13–17°C. Males with silvery breeding colour, with dark blotches. Females spawn a few eggs almost daily. Eggs are deposited into narrow fissures on stones, wood and live plants. Migratory in Livanjsko Polje. Larvae and juveniles benthic and solitary. Omnivorous. In females, the end of the intestine and of the oviduct and their openings are contained in a fleshy tube adnate to first simple anal ray functioning as ovipositor.



Aulopyge huegelii; Lake Buško, Bosnia-Herzegovina; courting (above) and spawning (below).

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Aulopyge huegelii; Lake Buško, Bosnia-Herzegovina; ~120 mm SL.

Lower lip of *Barbus* and *Luciobarbus* species

The terminology used in the literature to describe the shape of the lower lip in species of *Barbus* and *Luciobarbus* is often inconsistent or morphologically inaccurate, and uncritically compiled, adapted or translated. Here, we use exclusively the following expressions and definitions, based on our examination of material of all species.

In most species, the lower lip is thick and fleshy. In some, the median part of the lip is produced posteriorly into a **lobe** (Fig. 31a) (often described as tongue-like lobe or tri-lobed lower lip in the literature). Posteriorly, the lobe is not continuous with the skin of the throat; laterally, it is separated from the rest of the lip by notches. The lobe may be long, produced and pendulous, or squarish and reaching backward only to the angle of the mouth. In other species, the median part of the lower lip is thickened, but not produced into a lobe; it appears as a **swollen pad**, delimited posteriorly by a more or less deep groove (Fig. 31b); the posterior extremity of the pad is not free but continuous with the skin of the throat (often ambiguously described as a weakly developed lobe in the literature). The difference between a lobe and a pad may be slight; we make the distinction by gently running a needle under the lobe, arising in two possibilities: if it is a lobe, the needle can be inserted *under* the lobe and moved laterally under the lobe's entire width; or, if it is a pad, the needle may be inserted in the groove (if any) behind the pad, but cannot be moved under the pad. In the remaining species, the lower lip is **thin** and there is neither a median swollen area nor a median lobe (Fig. 31c).

In some species, there may be a transition from a pad to a lobe during growth; sometimes, different individuals or populations exhibit different conditions.

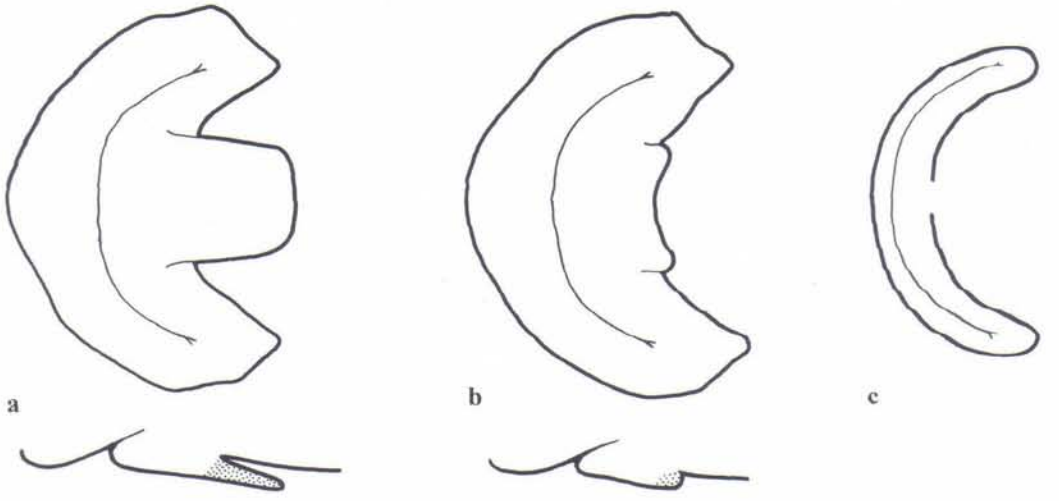

Figure 31 Lower lip of *Barbus* species: **a,** with a pendulous lobe; **b,** with a swollen pad; and **c,** thin, not modified. Above: ventral view; below: longitudinal section.

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Conservation status. EN B1ab(iii,v), due to small range, water abstraction and pollution. Population has declined sharply during 20th century due to habitat loss and pollution.

Further reading. Howes, 1987 (systematics, morphology); Šorić & Bănărescu, in Bănărescu, 1999: 367 (systematics, habitat, biology); Freyhof, 1997 (spawning, larvae).

Barbus and *Luciobarbus*

Barbels are medium to large fishes living near the bottom in a variety of habitats, from lakes and slow-flowing large rivers to hill streams. Their belly is somewhat flattened, the mouth is subinferior to inferior; they have two pairs of barbels and the lower lip is often swollen or modified (see Box). The last simple dorsal ray may be spinous and rigid or not, with posterior edge smooth or serrated on part or entire length, the extent and intensity of serration changing with growth. In many species, females have a larger anal fin than males, which is assumed to play a role in excavating the substrate for spawning. In all species, most (but not all) juveniles are covered with spots and blotches and, compared to adults, the last simple dorsal ray is shorter, less serrated and less rigid. Adults of many species are uniform brown to grey without spots or dots. Diagnosis is based on adults only.

The genus name *Barbus* has been used for a large number of species throughout Eurasia and Africa, although it has long been recognized that this was a very heterogeneous assemblage. As early as 1916 Southeast Asian species had already been organised into a coherent system and placed in different genera and it is now well established that there are no true *Barbus* in Asia outside Anatolia, the Tigris and Euphrates drainages, and the Caspian basin. Asian species earlier placed in *Barbus* belong to several different genera. Similarly, it is well known that species from equatorial and southern Africa belong to very distinct lineages, but this knowledge has unfortunately not yet been translated into a formal generic taxonomy. Nevertheless, the concept of a large and complex genus *Barbus* of unclear relationships is more than outdated.

European barbels are divided into two genera, *Barbus* and *Luciobarbus*. This division is strongly supported by molecular data and also morphological characters as the lip structure and the organisation of nuptial tubercles (few and large on the snout in *Luciobarbus* vs. numerous very small ones on head and anterior body in *Barbus*). *Barbus* includes only species from Europe and West Asia while *Luciobarbus* extends eastward to Iran and Aral basin, and to northern Africa. The two genera are not easily distinguished and therefore common keys are given below.

At the species level, the systematics of *Barbus* and *Luciobarbus* is still complicated. Several species from southern Europe are quite similar in appearance and earlier authors have expressed often contradictory views on species limits. Recent molecular data have shown that many southern European taxa recognized by earlier authors do indeed represent valid species.

Keys to species of *Barbus* and *Luciobarbus* in Europe

Black and Caspian Sea basins

1a – Predorsal length shorter than postdorsal length; 7½ branched dorsal rays; 16–25 gill rakers. ..... *L. brachycephalus*

1b – Predorsal length equal or longer than postdorsal length; 8½ branched dorsal rays; 7–18 gill rakers. 2

2a – Back between head and dorsal origin laterally compressed, forming a keel; sharp contrast between dark back and whitish or yellow belly. ..... *L. capito*

2b – Back not compressed or slightly compressed in front of dorsal origin; coloration of back and belly not sharply contrasted. 3

3a – Lower lip with a median swollen pad. 4

3b – Median part of lower lip produced posteriorly into a lobe. 7

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4a – 7–9 gill rakers.
..... *B. ciscaucasicus*

4b – 10–16 gill rakers.
..... 5

5a – Posterior margin of dorsal strongly concave; last simple dorsal ray spinous, flexible part about 20–40 % of its length, strong serrae along almost entire length of posterior edge; median part of lower lip not delimited posteriorly or delimited by a shallow groove.
..... *B. barbus*

5b – Posterior margin of dorsal slightly concave; flexible part of last simple dorsal ray about 50 % of its length, short serrae along median $^1/_3$–$^1/_2$ of posterior edge; median part of lower lip delimited posteriorly by a groove.
..... 6

6a – Dorsal origin above pelvic origin (Crimea).
..... *B. tauricus*

6b – Dorsal origin in front of pelvic origin (southern Black Sea drainage in Bulgaria and Turkey).
..... *B. bergi*

7a – Posterior margin of dorsal slightly concave; last simple dorsal ray strong or weak, flexible part up to about 50 % of its length, serrae along 10–90 % of posterior edge.
..... 8

7b – Posterior margin of dorsal straight or convex; last simple dorsal ray weak, flexible along its entire length, posterior edge not serrated.
..... 10

8a – Epithelial crests on predorsal scales (Fig. 28).
..... *B. kubanicus*

8b – No epithelial crests on scales.
..... 9

9a – Last simple dorsal ray slightly thickened, with few (3–5) very smooth to 30 short serrae along median third of posterior edge; usually 59–62 total lateral line scales (Vistula, upper Dniepr).
..... *B. waleckii*

9b – Last simple dorsal ray strong, with serrae along almost whole posterior edge; 64–71 + 3–4 lateral line scales (Thrace).
..... *B. cyclolepis*

10a – Paired fins with dark spots, at least dark pigments on rays forming 1–2 dark bars.
..... *B. balcanicus*

10b – Paired fins unspotted, rays unpigmented or with few dark pigments not forming dark bars.
..... 11

11a – Cheek and opercle unspotted or with a very few small spots; body plain or with faint dots and blotches slightly darker than background; caudal unspotted or with spots smaller than pupil diameter.
..... *B. carpathicus*

11b – Cheek and opercle with dark dots; body with dark dots and blotches much darker than background; caudal with elongate spots longer than pupil diameter.
..... *B. petenyi*

France, Great Britain, North and Baltic Sea basins

1a – Lower lip with a median swollen pad.
..... 2

1b – Median part of lower lip produced posteriorly into a lobe.
..... 3

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2a – Posterior margin of dorsal strongly concave; last simple dorsal ray spinous, rigid, serrated posteriorly; 53–63 total lateral line scales.
..... *B. barbus*

2b – Posterior margin of dorsal straight or slightly concave; last simple dorsal ray flexible, not serrated posteriorly; 44–48 +2 lateral line scales.
..... *B. meridionalis*

3a – Last simple dorsal ray slightly thickened, flexible segmented part about 50 % of its length, short serrae along median third of posterior edge.
..... *B. waleckii*

3b – Last simple dorsal ray weak, not serrated posteriorly, segmented along its entire length.
..... *B. carpathicus*

Apennine Peninsula and Adriatic basin in Slovenia and Croatia

1a – Lower lip without median lobe or swollen pad; 17–22 gill rakers; last simple dorsal ray slender, not serrated posteriorly in adults, occasionally with a few small, widely set serrae in individuals smaller than about 150 mm SL.
..... *L. graellsii*

1b – Lower lip with median lobe or swollen pad; 10–14 gill rakers; last simple dorsal ray serrated posteriorly or not.
..... 2

2a – Median part of lower lip produced posteriorly into a lobe.
..... 3

2b – Lower lip thick, with a median swollen pad.
..... 5

3a – Tip of dorsal pointed; posterior margin of dorsal concave; last simple dorsal ray finely serrated posteriorly; 58–77 + 3–4 lateral line scales; sides finely dotted in individuals larger than 150 mm SL; paired fins orange to grey without conspicuous spots.
..... *B. plebejus*

3b – Tip of dorsal rounded; posterior margin of dorsal straight or convex; last simple dorsal ray not serrated posteriorly; 36–57 + 2–4 lateral line scales; back, sides and fins speckled with large, irregular black dots.
..... 4

4a – 36–47 + 2–3 lateral line scales.
..... *B. caninus*

4b – 49–57 + 3–4 lateral line scales.
..... *B. balcanicus*

5a – Posterior margin of dorsal strongly concave; last simple dorsal ray spinous, with strong serrae along entire posterior edge; posterior part of scales (at least on caudal peduncle) pointed.
..... *B. barbus*

5b – Posterior margin of dorsal slightly concave; last simple dorsal ray feebly hardened, finely serrated along posterior edge in small individuals or serrae absent in individuals larger than about 150–200 mm SL; posterior part of scales (at least on caudal peduncle) rounded.
..... *B. tyberinus*

Balkan Peninsula (outside Danube drainage) and Dodecanese

1a – Lower lip thin, without median lobe or swollen pad (a few individuals of *L. albanicus* with median lobe).
..... 2

1b – Lower lip thick, with a median lobe or swollen pad.
..... 3

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2a – 48–55 + 2–3 lateral line scales (western Greece).
..... *L. albanicus*

2b – 39–44 + 2 lateral line scales (Kifissos and Sperchios drainages).
..... *L. graecus*

3a – Dorsal profile of snout distinctly concave in large individuals (Lakes Prespa).
..... *B. prespensis*

3b – Dorsal profile of snout straight to convex.
..... 11

4a – Tip of dorsal pointed; posterior margin of dorsal concave (Vardar, Aliakmon and Pinios drainages).
..... *B. macedonicus*

4b – Tip of dorsal rounded; posterior margin of dorsal straight or slightly concave.
..... 5

5a – Last simple dorsal ray serrated posteriorly in adults.
..... 6

5b – Last simple dorsal ray not serrated posteriorly in adults (sometimes granulated), not or slightly serrated in juveniles.
..... 8

6a – Dorsal profile of head almost straight in adults; usually 64–71 + 3–4 lateral line scales; 15–20 scale rows between lateral line and dorsal origin; eye diameter 2.4–3.2 times in snout length; depth of caudal peduncle 1.6–1.9 times in its length (Thrace).
..... *B. cyclolepis*

6b – Dorsal profile of head convex in adults; 54–64 + 3–4 lateral line scales; 12–16 scale rows between lateral line and dorsal origin; eye diameter 1.9–2.6 times in snout length; depth of caudal peduncle 1.3–1.8 times in its length
..... 7

7a – Lower lip with a swollen median pad; anterior scales of flank party embedded in skin; in adult females, tip of anal not reaching base of caudal (Volvi, Struma and Nestos drainages).
..... *B. strumicae*

7b – Lower lip with a median lobe; anterior scales of flank not embedded in skin; in adult females, tip of anal reaching to or beyond base of caudal (Sperchios and Pinios drainages).
..... *B. sperchiensis*

8a – Lower lip with a swollen median pad.
..... *B. peloponnesius*

8b – Lower lip produced posteriorly into a median lobe (a swollen median pad in some *B. euboicus* smaller than 120 mm SL).
..... 9

9a – Last simple dorsal ray serrated posteriorly in juveniles, usually smooth in adults; pectoral and pelvic triangular; when extended, width between tip of first and last branched pelvic rays greater than length of last ray (Fig. 32).
..... 10

9b – Last simple ray smooth posteriorly; pectoral and pelvic rounded; when extended, width between tip of first and last branched pelvic rays smaller than length of last branched ray.
..... 11

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10a – 46–52 + 3–4 lateral line scales; 10–12 scale rows between lateral line and dorsal origin; lower lip thin, with a short median lobe (or a median swollen pad in some individuals smaller than 120 mm SL) (Evia Island).
..... *B. euboicus*

10b – 50–57 + 2–3 lateral line scales; 13–15 scale rows between lateral line and dorsal origin; lower lip fleshy, with a conspicuous median lobe (Lesbos Island).
..... *B. pergamonensis*

11a – Simple pelvic ray distinctly shorter than second branched ray; posterior margin of dorsal straight to convex (Gallikos, Vardar and Aliakmon drainages).
..... *B. balcanicus*

11b – Simple pelvic ray about as long as second branched ray; posterior margin of dorsal straight to slightly concave (Drin to Aoos drainages).
..... *B. rebeli*

Iberian Peninsula

1a – Lower lip with a median lobe or pad.
..... 2

1b – Lower lip without median lobe or pad.
..... 5

2a – Numerous small black dots on body, more or less aligned in longitudinal series along scale rows; lower lip with a median lobe.
..... *B. haasi*

2b – Body plain, of if with dark marks, not aligned in longitudinal series; lower lip with a median pad.
..... 3

3a – Last simple dorsal ray not spinous, flexible, not serrated posteriorly; posterior margin of dorsal convex; head, body and fins with large, irregular black dots.
..... *B. meridionalis*

3b – Last simple dorsal ray spinous, rigid, serrated posteriorly; posterior margin of dorsal straight or concave; head, body and fins without black dots.
..... 4

4a – Posterior margin of dorsal concave; in lateral view, orbit close to but not touching dorsal head profile; depth of caudal peduncle about 1.3–1.6 times in its length; coloration of back and belly not sharply contrasted.

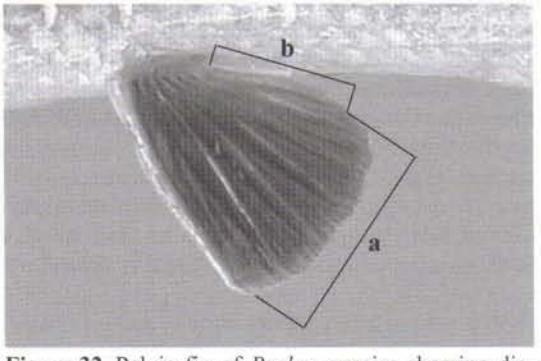

Figure 32 Pelvic fin of *Barbus* species showing distance between tip of first and last branched rays (**a**) and length of last ray (**b**).

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..... *L. steindachneri* (in part)

4b – Posterior margin of dorsal straight; in lateral view, orbit separated by some distance from dorsal head profile; depth of caudal peduncle about 1.2–1.4 times in its length; sharp contrast between dark back and whitish belly.
..... *L. sclateri* (in part)

5a – Dorsal profile of head straight to concave; in lateral view, orbit close or touching dorsal head profile.
..... 6

5b – Dorsal head profile convex; in lateral view, orbit at some distance from dorsal head profile.
..... 7

6a – In adults, in lateral view, orbit touching or protruding out of dorsal head profile.
..... *L. comizo*

6b – In adults, in lateral view, orbit close to but not touching dorsal head profile.
..... *L. steindachneri* (in part)

7a – Posterior margin of dorsal straight; depth of caudal peduncle about 1.2–1.4 times in its length; sharp contrast between dark back and whitish belly.
..... *L. sclateri*

7b – Posterior margin of dorsal concave; depth of caudal peduncle about 1.4–1.8 times in its length; coloration of back and belly not sharply contrasted.
..... 8

8a – Last simple dorsal ray flexible, not or only weakly serrated posteriorly in adults, occasionally with a few small, widely set serrae in juveniles (less than about 150 mm SL).
..... 9

8b – Last simple dorsal ray spinous and serrated posteriorly along at least part of its length.
..... 10

9a – Last simple dorsal ray not serrated posteriorly; mandibular barbel reaching beyond posterior margin of eye; tip of lower jaw covered by lower lip.
..... *L. graellsii*

9b – Last simple dorsal ray finely serrated, at least in juveniles; mandibular barbel not reaching posterior margin of eye; tip of lower jaw exposed, not covered by lower lip.
..... *L. guiraonis*

10a – Last simple dorsal ray spinous, strong, serrated posteriorly along most of its length; posterior edge of dorsal markedly concave, upper part of posterior edge about perpendicular to dorsal profile when fin is stretched (Fig. 33a).
..... *L. microcephalus*

10b – Last simple dorsal ray moderately spinous, serrated posteriorly along only about half of its length in adults, serrae small, rarely absent; posterior edge of dorsal straight or slightly concave, upper part of posterior edge at an angle to dorsal profile when fin is stretched (Fig. 33b).
..... *L. bocagei*

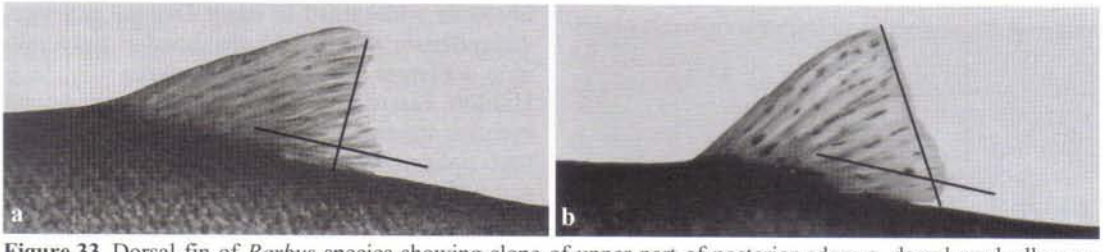

Figure 33 Dorsal fin of *Barbus* species showing slope of upper part of posterior edge: **a,** dorsal markedly concave, upper part of posterior edge about perpendicular to dorsal profile; **b,** dorsal slightly concave, upper part of posterior edge at an angle to dorsal profile.

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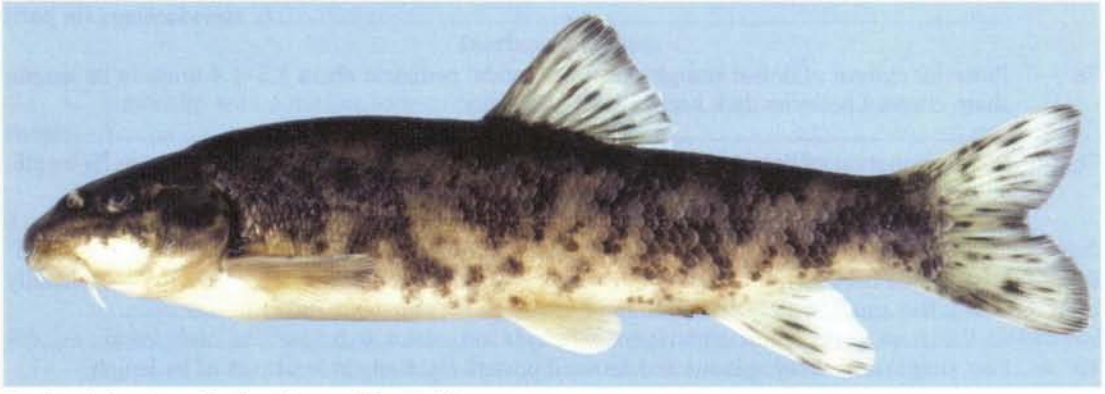
Barbus balcanicus; Kolpa, Danube drainage, Slovenia; 130 mm SL.



Barbus balcanicus; Vardar, Greece; 92 mm SL.

Barbus cf. *balcanicus*; lower Vardar, Greece; 99 mm SL.

Barbus balcanicus

Common name. Large spot barbel.

Diagnosis. Distinguished from other species of *Barbus* and *Luciobarbus* in Danube drainage, Adriatic basin and Balkan Peninsula by: ❍ last simple dorsal ray weak, not serrated posteriorly / ❍ lower lip thick, with a short median lobe / ❍ usually 9–12 scale rows between lateral line and dorsal origin / ❍ 8–10 scale rows between lateral line and pelvic origin / ❍ 49–57 + 3–4 lateral line scales / ❍ top of head with conspicuous black dots or spots, about size of pupil / ❍ cheek and opercle with dark dots / ❍ paired fins with dark spots, at least dark pigments on rays forming 1–2 dark bars / ❍ body with dark dots and blotches much darker than background / ❍ caudal with elongate spots longer than pupil diameter / ❍ simple pelvic ray distincly shorter than second branched ray. Size up to about 175 mm SL.

Distribution. Adriatic basin: Soca drainage (Italy, Slovenia). Danube drainage: upper Save, Archar, Krupaja, Vlasinsko and Nera systems, possibly more widespread in upper Danube drainage. Aegean basin: Gallikos, Vardar, Loudias and Aliakmon drainages (Greece, Macedonia).

Habitat. Fast to moderate-flowing premontane and montane streams and small rivers with gravel bottom. Spawns in riffles. Most abundant in rapids and riffles during day.

Biology. Moves to upper reaches for spawning. Spawns in May – July.

Conservation status. LC.

Remarks. This species is diagnosed mainly by

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Barbus barbus; South Bug drainage, Ukraine; ~350 mm SL.

Barbus barbus; Adour drainage, France; 183 mm SL.

molecular characters and difficult to distinguish from *B. carpathicus* and *B. petenyi* in the field. Characters given in the key may be of limited use. Some populations from the Gallikos, Aliakmon and lower Vardar have a longer dorsal with slightly concave margin, last simple dorsal ray granulous posteriorly along part of its length, a longer anal, and pointed caudal lobes. They possibly represent introgression with *B. strumicae*, or a distinct species.

Further reading. Dimovski & Grupče, 1987 (morphology, as *B. petenyi*); Kotlík et al., 2002 (description).

Barbus barbus

Common name. Barbel.

Diagnosis. Distinguished from other species of *Barbus* in France, Great Britain, Black, North, Baltic and Adriatic Sea basins and Apennine Peninsula by: ❍ lower lip thick, with a median swollen pad / ❍ tip of dorsal pointed / ❍ posterior margin of dorsal concave / ❍ last simple dorsal ray spinous, serrated along entire posterior edge / ❍ flexible segmented part of last simple dorsal ray about 20–40 % of its length / ❍ fine dark spots (or no spots) in individuals larger than 100 mm SL / ❍ 53–63 total lateral line scales / ❍ 12–14 scale rows between dorsal origin and lateral line / ❍ pelvic origin about below dorsal origin / ❍ scales with free posterior part pointed / ❍ scales on back with 1–5 well developed median longitudinal epithelial crests (Fig. 28). Size up to about 900 mm SL.

Barbus barbus; Rhine drainage, Germany; juvenile pattern, ~50 mm SL.

Distribution. North of the Pyrénées and Alps, from Adour (France) eastward to Neman (Lithuania, Russia) drainages, in rivers draining to Atlantic, North Sea and southern Baltic Sea; Danube to Dniepr drainages in northern Black Sea basin; southeastern England north to Yorkshire. In almost all Mediterranean drainages of France. Locally introduced in northern and central Italy, rivers Wear, Tees and Medway and most western drain-

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Barbus barbus; spawning; Danube drainage, Germany. A. Hartl

ages of England.

Habitat. From premontane to lowland reaches of clear, warm, medium sized to large rivers with fast current and gravel bottom. Occasionally in lakes. Spawns usually in very shallow, fast-flowing waters, in riffles. Overwinters often in large aggregations inactive or active in slow-flowing river habitats.

Biology. Adults often shoal, hiding under overhanging trees or bridges during day. Most active during dusk and dawn. Lives up to 15 years. Males usually spawn for the first time at 2–5 years, females 1–2 years later. Spawns in May – July, rarely until September when temperatures reach 14–16°C. Females spawn several times, usually at intervals of 10–15 days each season. Adults often undertake considerable spawning migrations. Lake populations migrate to tributaries. Individual females spawn with several males. Males assemble at spawning grounds and follow ripe females, often with much splashing, to shallow riffles. Males may exhibit courting or sneaking tactics in spawning sites. Courting males follow females to spawning site and, during the spawning act, one male swims head to head with the female. Sneaking males, waiting in the spawning site, then join the couple and try to fertilise eggs. Up to 130 males have been reported to be involved in a single spawning act. Females deposit 2–3 portions of non-sticky eggs into excavations made in the gravel. Feeding larvae drift a short distance from spawning site to shallow shoreline habitats. Larvae and juveniles are benthic, in very shallow shoreline habitats. They leave the shores for faster-flowing waters as they grow. Larvae and juveniles active during both day and night. Feeds on a wide variety of benthic invertebrates, small fish and sometimes on algae.

Conservation status. LC. Locally threatened by water pollution and river regulation, especially in Baltic drainages, Elbe, South Bug and Dniepr. Sharply decline due to construction of large reservoirs and pollution during 20th century. Stabilised at a moderate level since. Heavily impacted by pollution in central Europe but recovering.

Further reading. Almaça, 1981: 280 (systematics); Bănărescu et al., in Bănărescu & Bogutskaya, 2003: 43 (biology).

Barbus bergi

Common name. Bulgarian barbel.

Diagnosis. Distinguished from other species of *Barbus* in Black Sea basin by: ○ tip of dorsal slightly pointed / ○ posterior margin of dorsal slightly concave / ○ dorsal origin in front of pelvic origin / ○ last simple dorsal ray weak, serrated along lower 50–70 % of its length / ○ lower lip with a median swollen pad / ○ fine dark spots on body and dorsal, smaller than pupil / ○ usually 55–60 total lateral line scales. Size up to at least 290 mm SL.

Distribution. Western Black Sea basin: from Kamchiya (Bulgaria) to Düzdere drainages (Turkey).

Habitat. Fast to moderate flowing rivers and streams.

Biology. No data.

Conservation status. LC.

Further reading. Chichkoff, 1935: 305 (description); Psehev, 1971 (description).

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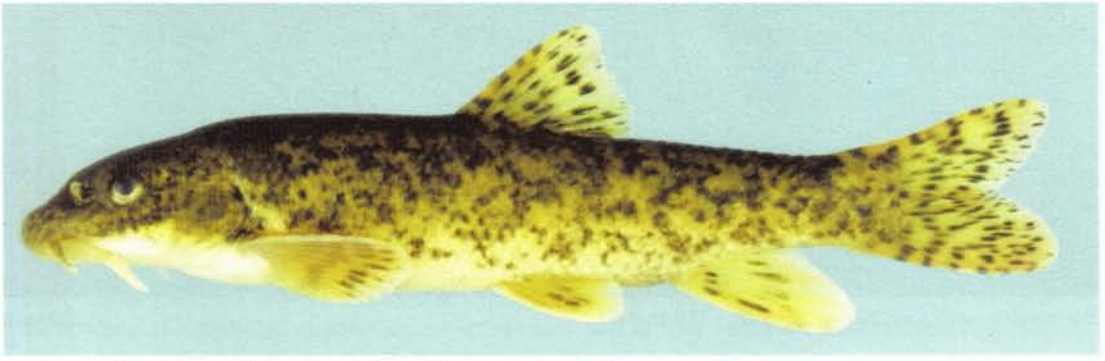
Barbus bergi; Papuc drainage, Turkey; 143 mm SL.



Barbus caninus; Ticino, Po drainage, Switzerland; 104 mm SL.

Barbus caninus

Common name. Insubrian barbel.

Diagnosis. Distinguished from other species of *Barbus* in Apennine Peninsula by: ○ 36–47 + 2–3 lateral line scales / ● back, sides and fins speckled with large, irregular black spots and blotches / ● peritoneum black / ○ last simple dorsal ray flexible, not serrated posteriorly / ○ 22–24 circumpeduncular scale rows / ● lower lip produced posteriorly into a median lobe. Size up to 250 mm SL.

Distribution. Adriatic basin, between Marecchia and Brenta drainages (Italy, Switzerland). Introduced in Arno and Ombrone drainages (Italy).

Habitat. Streams with swift water in hilly, subalpine areas. Spawns in fast-flowing water on gravel bottom.

Biology. Lives up to 5 years. Males reproduce for the first time at 1 year, females at 2. Spawns in May – July. Females spawn several portions of eggs each season. Feeds on benthic invertebrates.

Conservation status. EN A2ace. Still frequent in suitable habitats, but reported steep decline of number of spawning sites.

Remarks. Earlier misidentified as *B. meridionalis*. Records of *B. caninus* from Soca are based on *B. balcanicus*.

Further reading. Bianco, 1995b: 318 (systematics); Gandolfi et al., 1991 (biology); Bianco, in Bănărescu & Bogutskaya, 2003: 129 (biology).

Barbus carpathicus

Common name. Carpathian barbel.

Diagnosis. Distinguished from other species of *Barbus* in Danube drainage and northern central Europe by: ○ last simple dorsal ray weak, not serrated posteriorly, segmented on its entire length / ○ lower lip thick, with a median lobe / ○ 8–11 scale rows between lateral line and dorsal origin /

Barbus bergi

Barbus caninus

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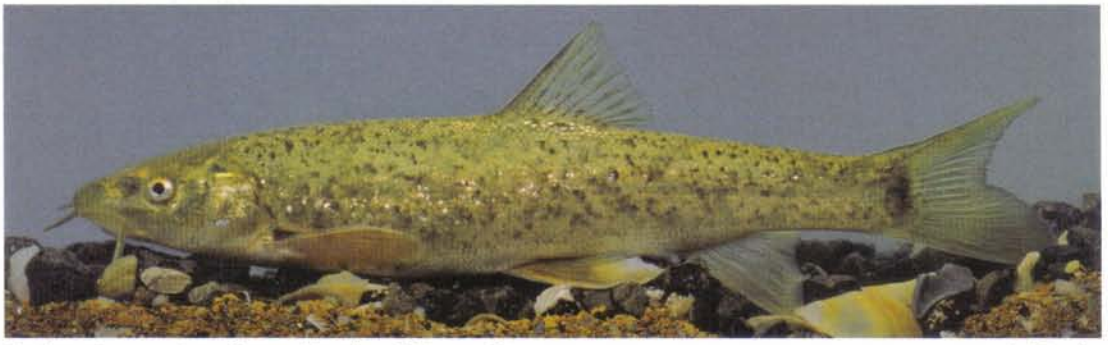
Barbus carpathicus; upper Dniestr drainage, Ukraine; ~120 mm SL.



Barbus ciscaucasicus; Samur, Russia; ~130 mm SL. A. Naseka

O 8–9 rows of scales between lateral line and pelvic origin / **O** top of head plain / **O** cheek and opercle unspotted or with very few small spots / **O** paired fins unspotted, rays unpigmented or with few dark pigments not forming dark bars / **O** body plain or with faint dots and blotches slightly darker than background / **O** caudal fin unspotted or with spots smaller than pupil diameter. Size up to 270 mm SL.

Distribution. Tisza system (Danube drainage), from Hron to Someş sub-systems, occasionally reaching to eastern Austria. Upper Vistula drainage in Slovakia and Poland; Wierzyca system (lower Vistula drainage, Poland); upper Dniestr drainage in Poland and Ukraine.

Habitat. Fast to moderate flowing premontane and montane streams and small rivers with gravel bottom. Most abundant in shallow rapids and riffles during summer. Moves to deeper places in winter. Spawns in fast-flowing water (0.8–1 m/s) of shallow (0.5–0.8 m) riffles.

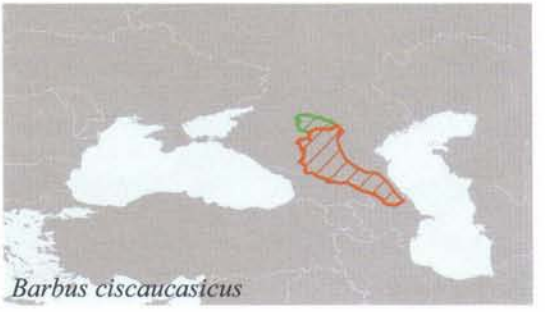
Biology. Spawns for the first time at 2–3 years and about 75 mm SL (males), 110–140 mm SL (females). Spawns in May – August at temperatures above 18°C. Females deposit 2–3 portions of non-sticky eggs into excavations made in gravel. Feeding larvae drift short distance from spawning site to shallow shoreline habitats. Larvae and juveniles benthic, in very shallow shoreline habitats. They leave the shores for faster-flowing waters as they grow. Feeds on a wide variety of benthic invertebrates and algae.

Conservation status. LC.

Remarks. This species is distinguished mainly on mtDNA characters and difficult to distinguish from *B. balcanicus* and *B. petenyi* in the field. Characters given in the key may be of limited use.

Further reading. Krupka & Holčík, 1976: 164 (description); Kotlík et al., 2002: 231 (description).

Barbus carpathicus



Barbus ciscaucasicus

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'Genetic' species and molecular systematics

The recent developments of molecular genetics (genetics based on molecular or biochemical markers) have led to renewed attention to the taxonomic diversity of European freshwater fishes. The attraction of a new tool, and the comfort of automated 'processing' of a supposed large number of characters that are then easily manipulated by computers, led to the illusion that 'molecular taxonomy' would resolve all the problems that 'traditional taxonomy' had not solved. Such a totalitarian view is outdated and even no longer accepted by molecular biologists. Molecular genetics is an important tool, but the truth is that problems left unresolved by 'traditional taxonomy' are not so because of technical limitations, but rather because there has been a refusal to accept that hitherto unrecognized taxonomic diversity exists in European fishes and because of the extremely small number of trained taxonomists working on European fishes.

The vast majority of problems resolved by 'molecular taxonomy' could have been solved almost instantly if competent taxonomists had been given access to funding and adequate series of well preserved material. "Molecular taxonomy" and "traditional taxonomy" do not represent separate, independent disciplines and are not antagonistic to each other: there is simply taxonomy, which is able to cope with all kinds of characters as long as they are produced and presented in a suitable way for taxonomic analysis. Molecular phylogeny shows the phylogeny of genes, not of species. This is especially true for mtDNA phylogenies as mitochondria are often transferred by introgressive hybridisation between species or even between genera. This implies that the results of molecular analysis need to be interpreted together with other sets of characters and should not be analysed independently. If the different sets of characters lead to contradictory conclusions, there is no reason to automatically discard one set of characters in favour of the others. Species may differ genetically in the absence of significant morphological differences, just as they may well differ morphologically in the absence of significant genetic differences.

In recent years, a few species have been described on the basis of genetic differences alone. In some of these cases, the authors claimed that there were few or no morphological differences. Whenever we were able to examine well preserved material of these taxa, we found only two cases (*Rhodeus amarus* vs. *R. meridionalis*; *Cottus gobio* vs. *C. rhenanus*) supporting such a claim In all other cases the authors had not critically examined all the available material. (But even so, *R. amarus* and *C. gobio* have wide ranges and are extremely variable, and most populations are distinguishable from *R. meridionalis* and *C. rhenanus*, respectively).

As with most other characters used in taxonomy, trenchantly different character states in molecular characters (except mtDNA) usually indicate distinct species; but the reverse is not true: little or no molecular difference may indicate the absence of taxonomic distinctiveness, or equally that a given character is uninformative.

In recent years, molecular studies have resulted in many proposals to change the classification at the generic level so as to reflect molecular phylogenies. We have been relatively conservative and ignored many of these proposals. Where we have not followed them, it is generally because we have noted that there were conceptual flaws in these hypotheses (for example, we do not divide *Neogobius*). The most common flaws are: the authors were not familiar with principles of systematics; the authors had not correctly identified the taxa; the conclusions were based on too few species or too few characters. Exactly the same problems arise with any phylogenetic hypotheses, and experience shows that many such changes are short lived.

A danger of strictly numerical (molecular) analyses is that it ignores biological reality (for example, the great diversity of modes of speciation) and devalues the experience of taxonomists familar with the whole variety of related organisms.

Barbus ciscaucasicus

Common name. Terek barbel.

Diagnosis. Distinguished from other species of *Barbus* and *Luciobarbus* in Black and Caspian Sea basins by: ● 7–9 gill rakers / ○ 8½ branched dorsal rays / ○ posterior ¼ of predorsal area laterally compressed, not forming a keel / ○ predorsal length longer than postdorsal length / ○ lower lip with median pad, without posterior groove / ○ 60–71 total lateral line scales / ○ height of dorsal 10–15 % SL in adults, tip rounded, when depressed not reaching anus / ○ last simple dorsal ray spinous, with 30–60 short serrae posteriorly / ○ flexible part of last simple dorsal ray about 30 % of ray length / ○ anal not reaching caudal base. Size up to 500 mm SL.

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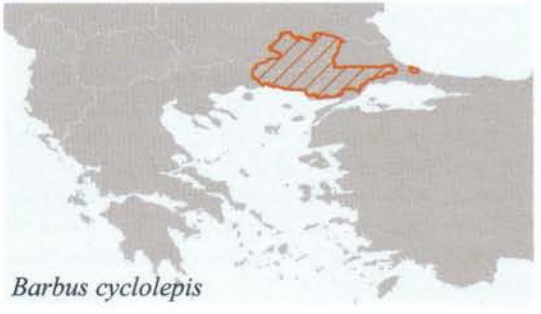
Barbus cyclolepis; Maritza, Greece; ~190 mm SL.

Barbus euboicus; Evia Island, Greece; 113 mm SL.

Distribution. Western Caspian basin, from Terek to Samur drainages in northern Caucasus, Daghestan and Azerbaijan. After construction of Kuma-Manych canal, invaded Chograiskoie Reservoir (Don drainage).
Habitat. Piedmont and montane stretches of rivers and streams with stone or gravel bottom. Ranges upstream to uppermost reaches in mountains.
Biology. Lives up to 7 years. Females spawn for the first time at 4 years, males at 2–3. Migrates upriver and spawns in shallow tributaries in March – September. Average female spawns about 9,000 eggs. Larvae and yearlings remain in spawning streams, adults migrate downriver. Feeds on benthic invertebrates, terrestrial insects and diatoms. In still-water habitats, feeds on terrestrial insects and zooplankton.
Conservation status. LC. Abundant in upper reaches of rivers and invasive in Don drainage.
Further reading. Khatukhov et al., 2001 (ecology); Bogutskaya, in Bănărescu & Bogutskaya, 2003: 163 (taxonomy, biology).

Barbus cyclolepis

Common name. Maritza barbel.
Diagnosis. Distinguished from other species of *Barbus* in Balkan Peninsula by: ○ last simple dorsal ray spinous, serrated posteriorly / ○ 10–13 scale rows between lateral line and pelvic origin / ○ 15–20 scale rows between lateral line and dorsal origin / ○ usually 64–71 + 3–4 lateral line scales / ○ anterior scales of flank partly embed-



Barbus cyclolepis

Barbus euboicus

watermanⓒ

Barbus haasi; Ebro drainage, Spain; ~100 mm SL. M. Bunzel-Drüke

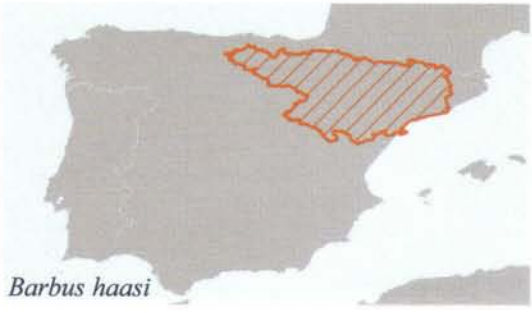
ded in skin / ○ head, body and fins with conspicuous black dots, smaller than pupil / ○ caudal with a few small dots and without distinct black margin / ○ lower lip with a median lobe in individuals larger than about 100 mm SL, a swollen pad in smaller ones / ○ eye diameter 2.4–3.2 times in snout length / ○ depth of caudal peduncle 1.6–1.9 times in its length. Size up to about 250 mm SL.
Distribution. Aegean Sea basin, from Vistonis drainage eastward (Greece, Bulgaria, Turkey). Black Sea basin, few rivers in Thracian Turkey, northwards to Istranca.
Habitat. Streams and rivers; prefers stretches with clear water and riffles.
Biology. Spawns in April – July.
Conservation status. LC.
Further reading. Karaman, 1971: 201 (morphology); Economidis & Bogutskaya, in Bănărescu & Bogutskaya, 2003: 181 (biology).

Barbus euboicus

Common name. Evia barbel.
Diagnosis. Distinguished from other species of *Barbus* in Balkan Peninsula by: ○ 46–52 + 3–4 lateral line scales / ○ 10–12 scale rows between lateral line and dorsal origin / ○ 7–8 scale rows between lateral line and pelvic origin / ○ last simple dorsal ray slender, serrated posteriorly along lower half in individuals less than about 100 mm SL, usually unserrated in larger ones / ○ lower lip with a short median lobe (or a median swollen pad in some individuals smaller than 120 mm SL) / ○ pectoral and pelvic triangular; when extended, width between tip of first and last branched pelvic rays greater than length of last ray (Fig. 32) / ○ posterior margin of dorsal slightly concave. Size up to about 180 mm SL.
Distribution. Greece: streams of southern half of Evia (Euboea) Island.
Habitat. Stream on gravel bottom, flow usually interrupted in summer when only a few pools may remain.
Biology. Spawns in May – June.
Conservation status. CR B1ab(i,ii)c(ii) + 2ab(i,ii)c(ii). In dry years, streams dry completely and species survives only in a few pools.
Further reading. Stephanidis, 1971b: 214 (description).

Barbus haasi

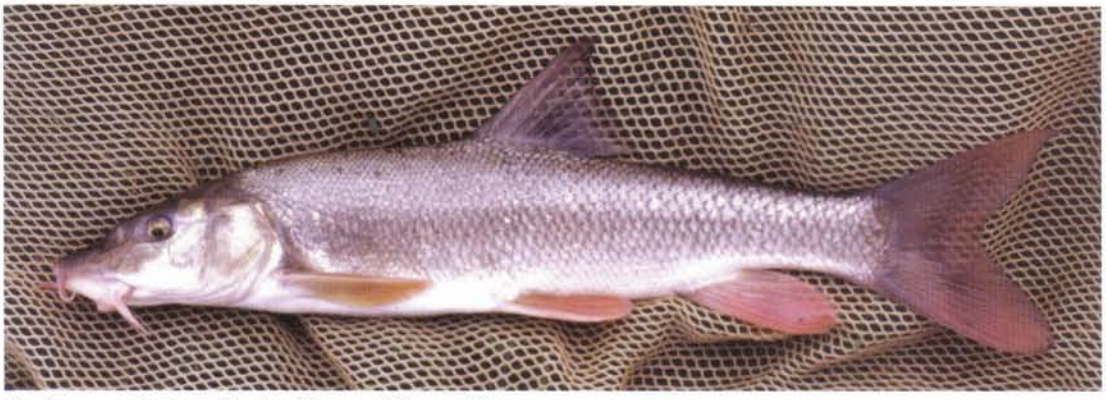
Common name. Catalonian barbel.
Diagnosis. Distinguished from other species of *Barbus* and *Luciobarbus* in Iberian Peninsula by: ● numerous small black dots on body, more or less aligned in longitudinal series along scale rows / ● anal, part of caudal and pelvic red in spawning season / ● lower lip with a median lobe / ○ last simple dorsal ray slender, with small or no serrae posteriorly / ○ 46–50 + 3–4 lateral line scales. Size up to about 250 mm SL.
Distribution. Mediterranean slope of Spain, from Llobregat to Riudecanyes drainages.
Habitat. Most frequent in upper, cooler stretches of streams, with current and stone bottom.
Biology. Spawns on vegetation and under stones. Feeds mainly on benthic macro-invertebrates, especially insect larvae. Spawns in April – June.
Conservation status. VU A2ce + 3ce. Declining due to water abstraction and habitat modification, which favour alien species.
Further reading. Almaça, 1983a: 36 (description); Doadrio & Perdices, in Bănărescu & Bogutskaya, 2003: 243 (biology).



Barbus haasi

watermanⓒ

Barbus kubanicus; Belaya, Kuban drainage, Russia; ~100 mm SL.



Barbus macedonicus; Vardar, Greece; 290 mm SL.

Barbus kubanicus

Common name. Kuban barbel.

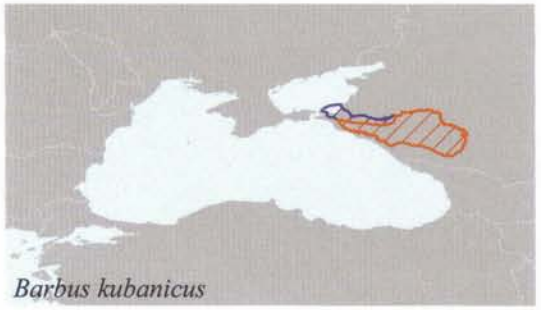
Diagnosis. Only species of genus in Kuban drainage. Distinguished from other species of *Barbus* in Black Sea basin by: ❍ lower lip thick, with a pendulous median lobe / ❍ tip of dorsal slightly pointed / ❍ posterior margin of dorsal straight or slightly concave / ❍ last simple dorsal ray spinous, strong, with serrae along almost entire ray / ❍ epithelial crests on scales (Fig. 28) / ❍ 56–69 total lateral line scales / ❍ pelvic origin about below dorsal origin. Size up to 620 mm SL.

Distribution. Kuban drainage and Sea of Azov close to Kuban estuary.

Habitat. Mountain and piedmont streams, with strong current, sand, gravel or rock bottom. Less abundant in lowland stretches and estuary. Spawns on gravel bottom.

Biology. Males reproduce for the first time at 3 years, females at 4. Spawns in May – August. Spawning run starts at end of March and peaks in May. Migrations may extend to uppermost reaches of tributaries. Female lays up to three portions of eggs (total up to 60,000). After spawning, adults migrate downstream and spend winter in main course of Kuban and lower reaches of tributaries. Larvae and small juveniles feed mostly on chironomids and algae. Larger juveniles and adults feed on a variety of benthic invertebrates and small fish.

Conservation status. LC. Widespread and abundant. Rare in lower Kuban since construction of Krasnodar dam.



Barbus kubanicus

Barbus macedonicus

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Barbus meridionalis; Bevera, France; 150 mm Sl.

Further reading. Berg, 1913: 120 (taxonomy); Musatova, 1957 (biology); Troitskiy & Tsunikova, 1988 (biology).

Barbus macedonicus

Common name. Macedonian barbel.

Diagnosis. Distinguished from other species of *Barbus* and *Luciobarbus* in Balkan Peninsula by: ○ length of last simple dorsal ray conspicuously greater than head depth, posterior margin concave / ○ last simple dorsal ray spinous, strong, serrated posteriorly along at least half of its length / ○ 14–17 scale rows between lateral line and dorsal origin / ○ lower lip thick, with swollen median pad or short lobe / ○ dark marks on flank only in juveniles / ○ 53–59 + 3–4 lateral line scales. Size up to about 650 mm SL.

Distribution. Vardar, Aliakmon and Pinios drainages (Greece, Macedonia).

Habitat. Main rivers, stretches with fast current, over stone and gravel bottom.

Biology. No data.

Conservation status. DD.

Further reading. Dimovski & Grupče, 1987 (morphology); Economidis, in Bănărescu & Bogutskaya, 2003: 271 (biology); Economidis & Bobori, in Bănărescu & Bogutskaya, 2003: 421 (as *B. thessalus*).

Barbus meridionalis

Common name. Mediterranean barbel.

Diagnosis. Distinguished from other species of *Barbus* and *Luciobarbus* in Apennine and Iberian Peninsulas and southern France by: ○ 44–48 + 2 lateral line scales / ○ head, back, sides and fins with large, irregular black dots / ○ last simple dorsal ray not spinous, flexible, not serrated posteriorly / ○ 24–28 circumpeduncular scale rows / ○ lower lip thick, with a median swollen pad. Size up to about 270 mm SL.

Distribution. Rivers draining to Mediterranean from Besos (near Barcelona, northeastern Spain) to Var (at Nice, southeastern France) drainages, including Rhône as far upriver as Lyon; some headwaters of Garonne basin in Ariège, Tarn and Aveyron (France), apparently native in most, but introduced in at least some upper Tarn localities.

Habitat. Upper and middle stretches of streams, with fast, clear and well oxygenated water. Also present in lowland where *B. barbus* is absent.

Biology. Spawns in May – July on gravel banks in fast-flowing water. Feeds mainly on invertebrates. In southern France, locally forms partly fertile hybrids with *B. barbus*.

Conservation status. NT. Gradually declining due to habitat modification, water abstraction.

Further reading. Doadrio & Perdices, in Bănărescu & Bogutskaya, 2004: 277 (description, biology).

Barbus peloponnesius

Common name. Peloponnese barbel.

Diagnosis. Distinguished from other species of *Barbus* and *Luciobarbus* in Balkan Peninsula by: ○ last simple dorsal ray not stronger than branched rays, not serrated posteriorly / ○ 47–53 + 2–3 lateral line scales / ○ 5–7 scale rows between lateral line and pelvic base / ○ head and body with small black spots (plain in some populations from Peloponnese) / ● often faint dark stripes or faint rows of dark spots along scale rows / ○ lower lip with a median swollen pad. Size up to about 190 mm SL.

Barbus meridionalis

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Barbus peleponnesius; Evinos, Greece; 118 mm SL.

Distribution. Western Greece: from Kalamas to Pamissos drainages.
Habitat. Lower and upper parts of streams, with stone bottom and current.
Biology. Matures at 2–3 years. Spawns in March – July on gravel. Fractional spawner. Feeds on aquatic invertebrates.
Conservation status. LC. Locally abundant and quite widely distributed, but most small streams are dry in summer. As a result, populations are greatly fragmented and several are threatened.
Further reading. Economou et al., 1994a: 23 (larvae); Barbieri et al., 2002a: 56 (biology); Economidis et al., in Bănărescu & Bogutskaya, 2003: 301 (biology [in part, includes several species]).

Barbus pergamonensis

Common name. Bergama barbel.
Diagnosis. Distinguished from other species of *Barbus* and *Luciobarbus* in Balkan Peninsula and around Aegean Sea by: ● 50–57 + 2–3 lateral line scales / ● 13–15 scale rows between lateral line and dorsal origin / ● 7–9 scale rows between lateral line and pelvic origin / ● last simple dorsal ray slender, with 11–15 serrae posteriorly along lower half in individuals less than about 90 mm SL, unserrated or only 3–4 small serrae at base of ray in larger ones / ● lower lip fleshy, thick, with a median lobe / ● pectoral and pelvic triangular; when extended, width between tip of first and last branched pelvic rays greater than length of last ray (Fig. 32) / ● posterior margin of dorsal slightly concave. Size up to at least 170 mm SL.
Distribution. Greece: Lesbos Island, stream Evergetoulas. Turkey: Aegean drainage from Bakir to Great Menderes.
Habitat. Streams and upper parts of rivers.
Biology. No data.
Conservation status. LC. A single population in European waters.
Further reading. Karaman, 1971: 203 (diagnosis); Stoumboudi et al., 2006: 131 (Lesbos population).

Barbus petenyi

Common name. Romanian barbel.
Diagnosis. Distinguished from other species of *Barbus* and *Luciobarbus* in Balkan Peninsula and Danube drainage by: ● last simple dorsal ray weak, not serrated posteriorly, segmented along entire length / ● lower lip thick, with a pendulous median lobe / ● usually 9–11 scale rows between lateral line and dorsal origin / ● usually 8–10 scale rows between lateral line and pelvic origin / ● top of head plain or with small black dots, smaller than pupil / ● cheek and opercle with dark dots / ● paired fins unspotted, rays unpigmented or with a few dark pigments not forming dark bars /

Barbus peloponnesius

Barbus pergamonensis

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Barbus pergamonensis; Gümüldür, Turkey; 200 mm SL.

Barbus petenyi; Arges, Danube drainage, Romania; ~90 mm SL.

○ body with dark dots and blotches much darker than background / ○ caudal with elongate spots, larger than pupil diameter. Size up to at least 250 mm SL.

Distribution. Danube drainage in Bulgaria and Romania: Mureş, Arges, Olt, Iskar, Jantra, Ialomita and Beli Vit systems. Kamchyia drainage (Black Sea basin of Bulgaria).

Habitat. Upper and middle stretches of streams and small rivers, with fast, clear and well oxygenated water.

Biology. No data.

Conservation status. LC. Still frequent in suitable habitats. Decline suspected and expected gradually to continue with on-going economic development.

Further reading. Kotlík & Berrebi, 2002 (genetics); Kotlík et al., 2002: 229 (description, distribution).

Barbus plebejus

Common name. Padanian barbel.

Diagnosis. Distinguished from other species of *Barbus* in Apennine Peninsula and Adriatic Sea basin by: ○ 58–77 + 3–4 lateral line scales / ○ in individuals larger than 150 mm SL back plain and sides finely dotted / ○ paired fins tinged with grey but without conspicuous spots / ○ peritoneum white / ○ last simple dorsal ray feebly spinous, flexible, finely serrated posteriorly / ○ lower lip with a median lobe. Size up to 600 mm SL and 6 kg.

Distribution. Adriatic basin from Tronto to Krka drainages (Italy, Switzerland, Slovenia, Croatia). Introduced on Tyrrhenian slope of central Italy.

Barbus petenyi

Barbus plebejus

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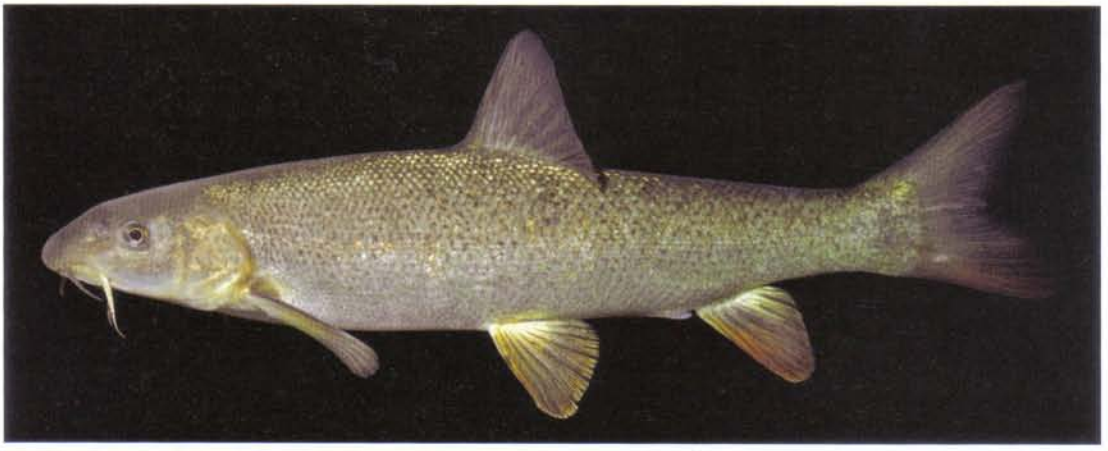
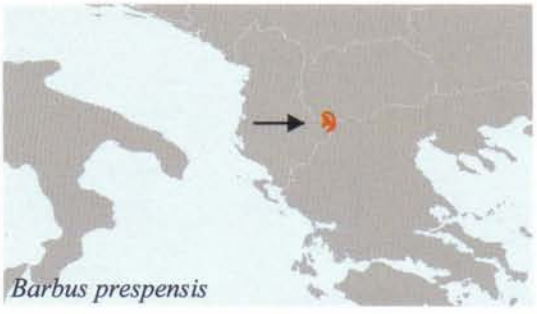


Barbus plebejus; Soca drainage, Italy; ~350 mm SL.

Barbus prespensis; Lake Prespa, Greece; 198 mm SL.

Habitat. In rivers (piedmont) and lakes. Preferential rheophile.
Biology. Spawns for the first time at 2–4 years, females 1 year later than males. Spawns in April – August, usually in May – July. Males assemble at spawning grounds and follow ripe females, often with much splashing, to shallow riffles. Females deposit non-sticky eggs into excavations made in gravel. Feeds on a wide variety of benthic invertebrates, small fish and sometimes on algae.
Conservation status. LC.
Further reading. Bianco, 1995b: 307 (systematics); Gandolfi et al., 1991: 198 (biology); Bianco, in Bănărescu & Bogutskaya, 2003: 341 (biology).



Barbus prespensis

Barbus prespensis

Common name. Prespa barbel.
Diagnosis. Distinguished from other species of *Barbus* and *Luciobarbus* in Balkan Peninsula by: ● dorsal profile of snout distinctly concave in large individuals / ○ last simple dorsal ray spinous, weakly serrated posteriorly, serrae restricted to about median half of ray / ○ 50–54 + 3 lateral line scales / ○ body covered by small, weakly marked black spots / ○ lower lip thick, fleshy, with a median lobe. Size up to about 240 mm SL.
Distribution. Prespa Lakes basin (Greece, Macedonia, Albania).
Habitat. Lake and tributaries. Spawns in tributaries or on gravel beaches in lake, especially near underwater springs.
Biology. Males reproduce for the first time at about 70 mm SL, females at 110 mm SL in Megali Prespa, at 135 and 160 mm SL, respectively, in Mikri Prespa. Spawns in April – July. Migrates to tributaries by night. Adults return to lake in early July and juveniles start to move to lake in late July, at about 15 mm SL. Feeds mainly on *Gammarus* in lakes and on insects in streams.
Conservation status. VU D2.
Further reading. Dimovski & Grupče, 1987 (mor-

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Barbus rebeli; Lake Ohrid, Macedonia; 138 mm SL.

Barbus sperchiensis; Pinios (Thessaly), Greece; ~85 mm SL.

phology); Catsadorakis et al., 1996 (biology, conservation); Economidis & Daoulas, in Bănărescu & Bogutskaya, 2003: 365 (description, biology).

Barbus rebeli

Common name. Western Balkan barbel.

Diagnosis. Distinguished from other species of *Barbus* and *Luciobarbus* in Balkan Peninsula by: ○ last simple dorsal ray weak, not serrated posteriorly / ○ 7–9 scale rows between lateral line and pelvic origin / ○ 10–12 scale rows between lateral line and dorsal origin / ○ head, body and fins with numerous small black dots, larger and darker on back / ○ 47–53 + 2–3 lateral line scales / ○ lower lip with small median lobe / ○ simple pelvic ray about as long as second branched ray / ○ posterior margin of dorsal straight to slightly concave. Size up to about 250 mm SL.

Distribution. Adriatic basin, from Drin to Aoos drainages, including Lakes Skadar and Ohrid (Montenegro, Albania, Macedonia, Greece).

Habitat. Lacustrine and riverine. In streams and rivers, prefers stretches with clear water and riffles.

Biology. No data.

Conservation status. LC. Widespread and locally abundant, but many small streams are dry in summer; populations are greatly fragmented and several potentially threatened. Albanian populations suspected to be impacted by overfishing.

Further reading. Koller, 1926: 316 (description).

Barbus sperchiensis

Common name. Sperchios barbel.

Diagnosis. Distinguished from other species of *Barbus* and *Luciobarbus* in Balkan Peninsula by: ○ last simple dorsal ray spinous, serrated posteriorly along at least lower half in adults / ○ 9–11 scale rows between lateral line and pelvic origin / ○ 12–16 scale rows between lateral line and dorsal origin / ○ 54–60 + 3–4 lateral line scales / ○ anterior scales of flank not embedded in skin / ○ head, body and fins with conspicuous black dots,

Barbus rebeli

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Barbus strumicae; Struma drainage, Greece; 113 mm SL.

Barbus tauricus; Salgir, Crimea, Ukraine; ~120 mm SL.

smaller than pupil, more or less organised into marbled patches / ❍ caudal with a few small dots and sometimes a narrow dark margin / ❍ lower lip with a median lobe. Size up to about 200 mm SL.
Distribution. Greece: Sperchios, Pinios and Cholorema drainages, streams in northern extremity of Evia (Eubea) Island.
Habitat. Streams and rivers; prefers stretches with clear water and riffles.
Biology. No data.
Conservation status. NT. Decline expected due to agricultural development and water abstraction.
Further reading. Stephanidis, 1971b: 221 (description), 223 (as *B. cholorematicus*); Economidis & Bogutskaya, in Bănărescu & Bogutskaya, 2003: 193 (biology).

Barbus strumicae

Common name. Strumica barbel.
Diagnosis. Distinguished from other species of *Barbus* and *Luciobarbus* in Balkan Peninsula by: ❍ last simple dorsal ray spinous, serrated posteriorly / ❍ 9–11 scale rows between lateral line and pelvic origin / ❍ 13–16 scale rows between lateral line and dorsal origin / ❍ 59–64 + 3–4 lateral line scales / ❍ anterior scales of flank partly embedded in skin / ❍ head, body and fins with conspicuous black dots, smaller than pupil, more or less organised into marbled patches / ❍ caudal with a few small dots and without distinct black margin / ❍ lower lip with a swollen median pad / ❍ eye diameter 1.9–2.5 times in snout length / ❍ depth of caudal peduncle 1.3–1.7 times in its

Barbus sperchiensis

Barbus strumicae

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Barbus tyberinus; Ombrone drainage, Italy; ~190 mm SL.

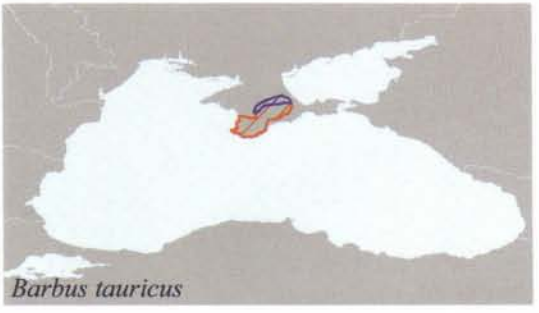
length. Size up to about 240 mm SL.
Distribution. Aegean Sea basin, from Volvi to Nestos drainages (Greece, Macedonia, Bulgaria).
Habitat. Streams and rivers; prefers stretches with clear water and riffles.
Biology. Reaches up to 7 years. Spawns for the first time at 2 years. Spawns in June.
Conservation status. LC, due to decline in habitat quality and (locally) overfishing.
Further reading. Dimovski & Grupče, 1987 (morphology); Neophitou, 1987 (biology); Economidis & Bogutskaya, in Bănărescu & Bogutskaya, 2003: 191 (biology).

Barbus tauricus

Common name. Crimea barbel.
Diagnosis. Only species of genus in Crimea Peninsula. Distinguished from other species of *Barbus* in Black Sea basin by: ○ tip of dorsal slightly pointed / ○ posterior margin of dorsal slightly concave / ○ last simple dorsal ray weak, serrated along its middle, on 50–70 % of its length / ○ lower lip with a median swollen pad / ○ fine dark spots or large blotches in individuals larger than 80 mm SL / ○ small epithelial crests on scales / ○ 51–63 total lateral line scales / ○ pelvic origin about below dorsal origin. Size up to 700 mm SL.
Distribution. Restricted to seven streams of Crimea (Black and Azov Sea basins).
Habitat. Widespread, from mountain streams with strong current to brackish estuaries. Prefers river stretches at 100–600 m above sea level.
Biology. Males reproduce for the first time at 2 years, about 65 mm SL, females at 3 years, about 100 mm SL. Moves upstream into upper reaches, or near rapids, to spawn on gravel or rock bottom. Females lay eggs in 1–3 portions. Eggs are non-sticky and lie among or under pebbles until hatching. At beginning of winter, moves to deeper places with less current and stops feeding. Feeds mainly on zoobenthos.
Conservation status. VU B1ab(i,ii,iii,v). Still abundant in streams Bel Bek and Kacha. Rare in streams Salgir, Chornaya and Alma due to pollution (Salgir) and water abstraction for irrigation (Alma). Water abstraction expected to increase in the immediate in all streams of Crimea.
Further reading. Movchan & Smirnov, 1981 (description, biology); Bogutskaya et al., in Bănărescu & Bogutskaya, 2003: 398 (description, biology [in part, includes several species]).

Barbus tyberinus

Common name. Horse barbel.
Diagnosis. Distinguished from other species of *Barbus* in Apennine Peninsula by: ○ 47–62 total lateral line scales / ● back plain, sides with conspicuous dark spots / ○ paired fins spotted / ○ peritoneum grey / ○ last simple dorsal ray feebly spinous, finely serrated posteriorly in small individuals; over about 150–200 mm SL, ray weak and serrae tend to disappear / ○ lower lip with a median swollen pad / ○ scales with free posterior part rounded. Size up to at least 400 mm SL and 4 kg.
Distribution. Italy: Tyrrhenian Sea basin, between rivers at Genova and Sele drainage; Adriatic basin, from Essino to Ofanto drainages. Introduced in other drainages in Italy.
Habitat. Rivers (piedmont) and lakes. Preferential rheophile. Moderate flowing waters of warm rivers and streams.
Biology. Lives up to 9 years. Males reach maturity at 2 years, females at 4, but in small streams, males may reach maturity at 1 year, 50 mm SL.



Barbus tauricus

watermanⓒ

Barbus waleckii; Dniestr, Ukraine; ~180 mm SL.

Spawns in April – June, in shallow water, over sand or gravel bottom. Multiple spawner. Breeding males have small tubercles on head and predorsal area. Feeds mainly on aquatic plants and invertebrates.

Conservation status. LC. Still widespread and locally abundant. Slow decline expected due to loss of habitat as a result of water abstraction, habitat alteration and hybridisation with introduced *B. barbus* and *B. plebejus*.

Further reading. Bianco, 1995b: 313 (systematics); Tancioni et al., 2001 (biology); Bianco, in Bănărescu & Bogutskaya, 2003: 427 (description, biology).

Barbus waleckii

Common name. Vistula barbel.

Diagnosis. Distinguished from other species of *Barbus* in Baltic and Black Sea basins by: ○ last simple dorsal ray slightly thickened, with 0– 30 small serrae posteriorly along median third / ○ flexible segmented part of last simple dorsal ray about 50 % of ray length / ○ lower lip thick, with a pendulous median lobe / ○ 52–70 (usually 59–62) total lateral line scales / ○ 11–12 scale rows between dorsal origin and lateral line (vs. 13–15 in sympatric *B. barbus*) / ○ pelvic origin slightly to clearly behind dorsal origin / ○ scales with free posterior part rounded / ○ no epithelial crests on scales. Size up to 340 mm SL.

Distribution. Vistula drainage (mainly San and Wisloka systems) downstream to Wilga (about 50 km from Warsaw), upper Dniestr basin in Poland and Ukraine. Similar barbels from upper Tisza system (Danube drainage) may belong to this species.

Habitat. Rather small rivers with moderate to fast current in piedmont and montane zones at 200–600 m above sea level. Prefers stone, gravel, pebble or sand bottom and river stretches with rapids and deep holes. Spawns in shallow places over pebble bottom with fast current and clear water with high oxygen concentrations.

Biology. Males reproduce for the first time at 2 years, females at 4–5. Spawns in May – July. At beginning of spawning season, migrates upriver to shallow, smaller tributaries. Does not migrate for long distances. Usually moves along main course of stream during feeding season. Spawning peaks in evening, at sunset. Males and females splash. Individual females actively dig holes with anal, into which eggs are released. Probably spawns 2–3 times during a spawning season. Feeds on benthic invertebrates.

Conservation status. LC. Slow decline expected to continue with on-going economic development.

Remarks. *B. waleckii* has been regarded as a hybrid between female *B. barbus* and male *B. carpathicus*. Available data suggest that individuals of *B. waleckii* are not first generation hybrids, and that they have their own biological and reproduction characteristics; they might nevertheless be a species of hybrid origin. Pending demonstration

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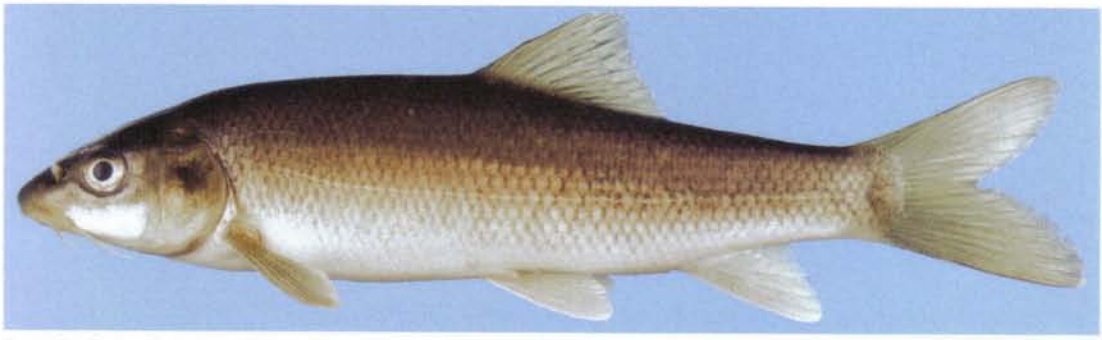

Luciobarbus albanicus; Pinios (Peloponnese), Greece; 135 mm SL.

that *B. waleckii* is not a distinct reproductive lineage, it is recognized as a valid species.
Further reading. Rolik, 1970: 401 (description), 1971: 259 (biology); Bogutskaya et al., 2004 (systematics).

Luciobarbus albanicus

Common name. Strossidi.
Diagnosis. Distinguished from other species of *Barbus* and *Luciobarbus* in Balkan Peninsula by: ○ last simple dorsal ray slender, spinous and serrated posteriorly along half to entire length / ○ posterior margin of dorsal straight / ○ most individuals with lower lip thin, without median lobe; some individuals with thick lips and median lobe / ○ 48–55 + 2–3 lateral line scales / ○ 20–24 circumpeduncular scale rows / ○ large tubercles on snout in large individuals. Size up to at least 500 mm SL.
Distribution. Western Greece, from Kalamas to Mornos (except Acheron) and Pinios drainages (Peloponnese), including Lakes Trichonis, Amvrakia and Pamvotis.
Habitat. Lakes and lower course of rivers, with mud to sand bottom.
Biology. Spawns for the first time at 3–4 years, lives up to 14 years. Spawns in May – July. Fractional spawner. Spawns in both lakes and their tributaries. Individual females spawn with 3–7 males on sandy beaches, especially near estuaries of tributaries. Eggs are non-adhesive. Larvae and juveniles form small monospecific schools in bays and harbours. Feeds on algae, plant material, insect larvae and detritus.
Conservation status. LC.
Remarks. Despite its scientific name, does not occur in Albania.
Further reading. Daoulas & Economidis, 1989 (age, feeding); Economou et al., 1994a: 23 (larvae); Economidis & Herzig-Straschil, in Bănărescu & Bogutskaya, 2003: 22 (systematics).

Luciobarbus bocagei

Common name. Iberian barbel.
Diagnosis. Distinguished from other species of *Barbus* and *Luciobarbus* in Iberian Peninsula by: ○ last simple dorsal ray moderately spinous, serrated posteriorly only along about half of its length in adults, serrae small, rarely absent / ○ posterior edge of dorsal slightly concave, upper part of posterior edge at an angle to dorsal profile when fin is stretched (Fig. 33b) / ○ lower lip without median lobe or pad / ○ tip of lower jaw exposed, not covered by lower lip / ○ head length 25–28 % SL / ○ 44–49 + 3 lateral line scales. Size up to about 800 mm SL.
Distribution. Atlantic slope of Spain and Portugal, from Lima to Sado drainages.
Habitat. Middle and lower reaches of streams, with slow current.
Biology. Males reproduce for the first time at 3 years (70 mm), females at 6–8 years (180–200 mm). Lives up to 11 years. Moves to areas of faster current for spawning, mainly in May – June.

Luciobarbus albanicus

Luciobarbus bocagei

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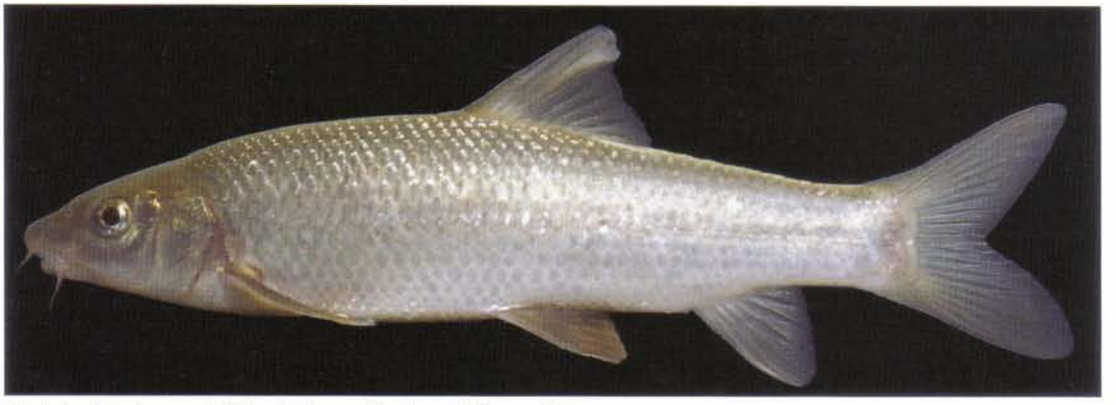
Luciobarbus bocagei; Douro drainage, Spain; ~80 mm SL.



Luciobarbus bocagei; Tajo drainage, Spain; ~150 mm SL.

Feeds on detritus and benthic invertebrates.
Conservation status. LC.
Further reading. Almaça, 1967: 179 (description), 1983a: 35 (diagnosis); Doadrio, 2001: 144 (biology); Almaça & Bănărescu, in Bănărescu & Bogutskaya, 2003: 98 (biology).

Luciobarbus brachycephalus

Common name. Shorthead barbel.
Diagnosis. Distinguished from other species of *Barbus* and *Luciobarbus* in Caspian Sea basin by: ● predorsal length shorter than postdorsal length / ● usually 7½ branched dorsal rays / ○ 16–25 gill rakers / ○ back between head and dorsal origin laterally compressed, forming a keel / ○ 62–90 (usually 65–77) total lateral line scales / ○ lower lip thin, without median lobe or pad. Size up to about 1000 mm SL and 21 kg.
Distribution. Southern and western Caspian Sea; Aral basin; River Chu (Kazakhstan). For spawning, migrates up larger tributaries of western and southern coasts: Terek, Samur, Kura, lower Aras. Rarely in lower Volga (up to Volgograd) and Ural.
Habitat. At sea, at depths of up to 25 m. In rivers, in deep stretches with gravel or stone bottom. Spawns in fast-flowing water at sites with hard bottom, 1–2 m deep.
Biology. Semi-anadromous and riverine populations. Spawns for the first time at about 500–700 mm SL, 5–7 years, females later than males. Spawns in April – August, with peak at 23–27°C. Some individuals start spawning migration in late summer–autumn and spawn following spring after overwintering in river. Some enter rivers in early spring and spawn same year. Females lay 100,000–1,250,000 bright yellow eggs, in 2–3 portions during a single season. Eggs are semipelagic and hatch while drifting downstream after at least 2 days at 25°C. Larvae settle into places with slow current; after 2–12 months juveniles drift downstream to sea (or reservoir if river is dammed). In freshened parts of sea, feeds mainly on benthic crustaceans. Does not feed while migrating upstream. At spawning sites, starts to feed again, mainly on insects, juveniles of other fishes, rarely on algae, seeds and other plant material.
Conservation status. VU A2cd. Stocks in Russia, Azerbaijan, Iran and Kazakhstan sharply declined due to massive habitat alterations. Now very rare in Caspian Sea basin. Extirpated in Aral Sea, still regularly found in middle Amu Darya drainage. Most likely continuing to decline due to ex-

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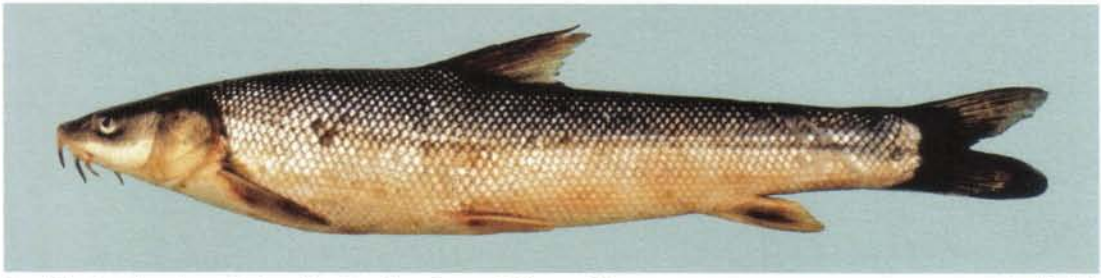


Luciobarbus brachycephalus; Caspian Sea, Iran; ~250 mm SL. A. Abdoli

Luciobarbus capito; Caspian Sea, Iran; ~300 mm SL. A. Abdoli

panding hydroelectric development, overfishing in estuaries and strong ecological impacts on Caspian and Aral Sea basins.

Further reading. Abdurakhmanov, 1962: 183 (biology); Magomedov, 1981 (biology); Mitrofanov et al., 1988: 24 (description, biology); Bogutskaya, in Bănărescu & Bogutskaya, 2003: 112 (biology).

Luciobarbus capito

Common name. Bulatmai barbel.

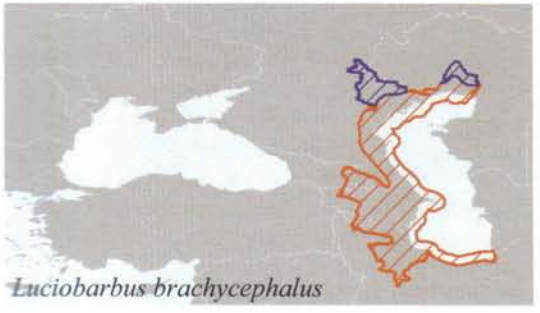
Diagnosis. Distinguished from other species of *Barbus* and *Luciobarbus* in Caspian Sea basin by: ○ lower lip thin, without median lobe or pad / ○ 12–18 gill rakers / ○ 8½ branched dorsal rays / ○ back between head and dorsal origin laterally compressed, forming a keel / ○ predorsal length longer than postdorsal length / ○ 52–72 (usually 60–66) total lateral line scales. Size up to about 800 mm SL and 15 kg.

Distribution. Caspian basin, for spawning migrates up larger tributaries of western and southern coasts, from Volga southward to Atrek (Iran). Was always very rare in Volga. Aral basin, in Amu Darya, Syr Darya and Chu drainages.

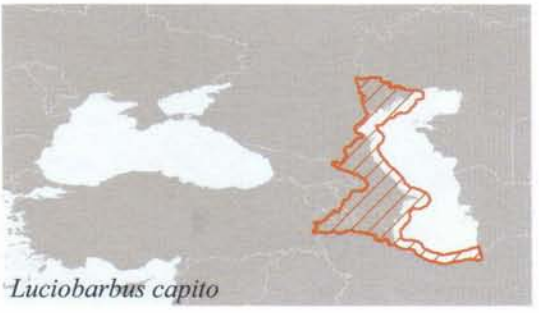
Habitat. At sea, mostly close to shores. Forages also in estuaries. Spawns in lowland streams and rivers on sand-gravel bottom, usually in strong current.

Biology. Semi-anadromous and non-anadromous individuals and populations, rarely landlocked in reservoirs. Spawns for the first time at 3–7 years, females later than males, over 200 mm SL. Spawns in April – August. Males are annual spawners, females apparently spawn every 2–3 years. Non-anadromous populations start migration in late summer–autumn and spawn following spring, but some enter rivers in early spring and spawn same year. Migrates to uppermost tributaries of rivers. Non-anadromous populations migrate just before spawning to upper stretches of tributaries, or spawn in lakes and reservoirs on sand to mud bottom. Females lay 15,000–125,000 light grey eggs. Larvae feed on zooplankton and small benthic invertebrates. Juveniles and adults feed on invertebrates, algae, detritus, plant material, and small fishes.

Conservation status. VU A2cd. Terek and Kura



Luciobarbus brachycephalus



Luciobarbus capito

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Luciobarbus comizo; Guadiana drainage, Spain; 127 mm SL.

were most important spawning rivers in Caspian basin. Very rare in Terek today. Rare and sharply reduced semi-anadromous populations everywhere in Caspian basin. Decline expected to continue due to increasing hydroelectric development, overfishing in estuaries, and strong ecological impacts on Caspian basin. Non-anadromous populations still abundant in many rivers of southern Caspian basin. Still regularly found in Aral Sea basin.
Further reading. Kazancheyev, 1981 (biology); Bogutskaya et al., in Bănărescu & Bogutskaya, 2003: 147 (description, biology).

Luciobarbus comizo

Common name. Comizo barbel.
Diagnosis. Distinguished from other species of *Barbus* and *Luciobarbus* in Iberian Peninsula by: ● in lateral view, orbit touching or protruding out of dorsal head profile / ● dorsal head profile concave in adults / ○ last simple dorsal ray spinous, strongly serrated posteriorly / ○ lower lip thin, without median lobe / ○ tip of lower jaw covered by lower lip / ○ head length 27–34 % SL / ○ snout length 2.3–2.8 times in HL / ○ 48–53 total lateral line scales. Size up to about 800 mm SL.
Distribution. Tagus and Guadiana drainages (Spain, Portugal). Extirpated in Guadalquivir drainage (Spain).
Habitat. Lower course of large, deep rivers, with slow current.
Biology. Reproduction not studied, probably in May – June. Juveniles feed on invertebrates. Large, adult individuals are mainly piscivorous. .
Conservation status. VU A2ce. Gradually declining due to water abstraction and habitat modification, which favour alien species.
Remarks. Often misspelled *B. comiza*.
Further reading. Doadrio, 2001: 147 (biology); Almaça & Bănărescu, in Bănărescu & Bogutskaya, 2003: 173 (description, biology).

Luciobarbus graecus

Common name. Skarouni.
Diagnosis. Distinguished from other species of *Barbus* and *Luciobarbus* in Balkan Peninsula by: ● 39–44 + 2 lateral line scales / ○ 18–20 circumpeduncular scale rows / ○ large tubercles on snout in large individuals / ○ last simple dorsal ray slender, serrated posteriorly along half to entire length / ○ posterior margin of dorsal straight / ○ lower lip thin, without median lobe. Size up to at least 500 mm SL.
Distribution. Greece: Kifissos and Sperchios drainages (including Lakes Yliki and Paralimni).
Habitat. Streams with stone and gravel bottom, lakes.
Biology. Spawns in April – July. Eggs hatch in 5 days at 22°C. Feeds on benthic invertebrates.
Conservation status. EN B1ab(i,ii,iii,iv) + 2ab (i,ii,iii,iv).
Further reading. Bianco, 1999: 129 (conservation status, diagnosis; as *Messinobarbus carottae*);

Luciobarbus comizo

Luciobarbus graecus

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Luciobarbus graecus; Kifissos drainage, Greece; about 250 mm SL (dorsal fin damaged, anterior rays missing).

Luciobarbus graellsii; Ebro drainage, Spain; ~120 mm SL. M. Bunzel-Drüke

Daoulas et al., 2001: 267 (biology); Economidis & Herzig-Straschil, in Bănărescu & Bogutskaya, 2003: 219 (taxonomy, description).

Luciobarbus graellsii

Common name. Ebro barbel.

Diagnosis. Distinguished from other species of *Barbus* and *Luciobarbus* in Iberian Peninsula by: O last simple dorsal ray slender, not serrated posteriorly in adults, occasionally with a few small, widely set serrae in individuals smaller than about 150 mm SL / O 43–48 + 2–3 lateral line scales / O posterior barbel reaching beyond posterior margin of eye / O lower lip thick, without median lobe / O tip of lower jaw covered by lower lip. Size up to 650 mm SL.

Distribution. Spain: from Ebro to Ter drainages on Mediterranean slope and westward to Ason drainage on Atlantic slope. Introduced to Fiora, Ombrone and Albegna drainages (central Italy) around 1998.

Habitat. Lower and middle reaches of rivers, with slow current. Prefers areas with vegetation and shore cover, migrates to upstream areas with faster current and gravel or stone bottom for spawning.

Biology. Lives up to 16 years. Spawns for the first time at 4 years, 150–200 mm SL. Spawns in May – August. Generally feeds on algae and aquatic macro-invertebrates.

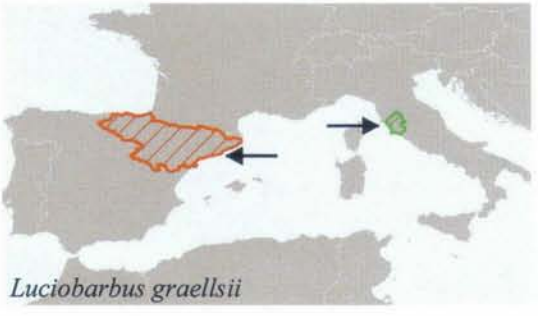
Conservation status. LC.

Further reading. Doadrio, 2001: 150 (biology); Bianco & Ketmaier, 2001 (introduction); Almaça & Bănărescu, in Bănărescu & Bogutskaya, 2003: 227 (biology).

Luciobarbus guiraonis

Common name. Valencia barbel.

Diagnosis. Distinguished from other species of



Luciobarbus graellsii

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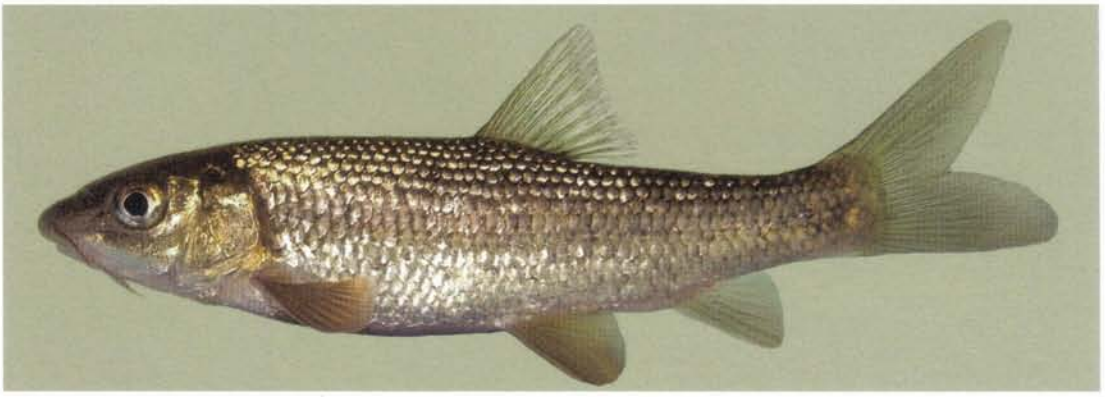


Luciobarbus guiraonis; Jucar drainage, Spain; ~100 mm SL. L. Kalous

Barbus and *Luciobarbus* in Iberian Peninsula by: O last simple dorsal ray slender, serrated posteriorly in juveniles, not serrated or only with very weak serrae in adults / O 45–49 + 3 lateral line scales / O posterior barbel not reaching posterior margin of eye / O lower lip without median lobe / O tip of lower jaw exposed, not covered by lower lip. Size up to about 500 mm SL.

Distribution. Spain: in streams draining to Mediterranean, between Vinalopo and (but not including) Ebro drainages, and in a few headwaters of Guadiana drainage.

Habitat. Most common in middle and lower reaches of rivers. In spawning season, moves to upstream stretches.

Biology. Lives up to at least 7 years. Spawns in April – June.

Conservation status. VU A3ce. Declining due to water abstraction and habitat modification, which favour alien species.

Further reading. Almaça, 1983b (description); Doadrio & Perdices, in Bănărescu & Bogutskaya, 2003: 235 (biology).

Luciobarbus microcephalus

Common name. Small-head barbel.

Diagnosis. Distinguished from other species of *Barbus* and *Luciobarbus* in Iberian Peninsula by: O last simple dorsal ray spinous, strong, serrated posteriorly along most of its length / O posterior edge of dorsal strongly concave, upper part about perpendicular to dorsal profile when fin is stretched (Fig. 33a) / O 45–50 + 3 lateral line scales / O head length 22–27 % SL / O lower lip thin, without median lobe or pad / O tip of lower jaw exposed, not covered by lower lip. Size up to about 400 mm SL.

Distribution. Guadiana drainage (Spain, Portugal); records from middle Tago (Spain) require confirmation.

Habitat. Middle course of large, deep rivers, with slow current.

Biology. Feeds on detritus and benthic invertebrates. Spawns in April – June.

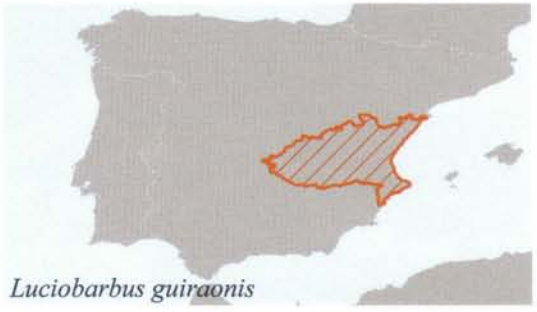
Conservation status. VU A2ce+3ce. Gradually declining due to water abstraction and habitat modification, which favour alien species.

Further reading. Almaça, in Bănărescu & Bogutskaya, 2003: 287 (description, biology).

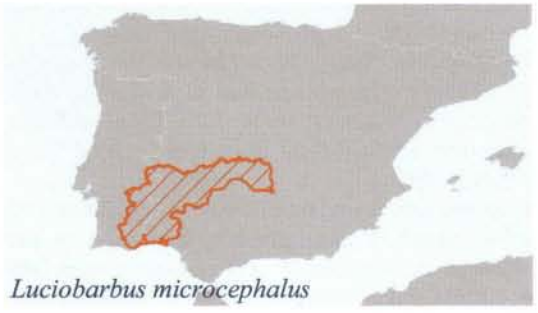
Luciobarbus sclateri

Common name. Andalusian barbel.

Diagnosis. Distinguished from other species of *Barbus* and *Luciobarbus* in Iberian Peninsula by: ● sharp contrast between dark back and whitish belly in adults larger than 300 mm SL / ● caudal peduncle stout, depth about 1.2–1.4 times in its length / O head length 24–29 % SL / O 42–45 + 3 lateral line scales / O last simple dorsal ray hardened and rigid on ½-¾ of its length, with small



Luciobarbus guiraonis



Luciobarbus microcephalus

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Luciobarbus microcephalus; Guadiana drainage, Spain; ~80 mm SL (mouth open).

Luciobarbus sclateri; Guadalquivir drainage, Spain; ~150 mm SL (contrast between dark back and whitish belly not distinct at this size).

serrae posteriorly along most of length / ○ lower lip with or without (most individuals) median lobe / ○ tip of lower jaw covered by lower lip. Size up to about 350 mm SL.

Distribution. Southern Spain and Portugal: from Segura to Mira drainages.

Habitat. Occurs in a variety of habitats; most abundant in large rivers and streams with slow to moderate current. Avoids upper, cold water streams.

Biology. Lives up to about 18 years. Males reproduce for the first time at 2–4 years (7–9 cm), females at 6–7 years (11–16 cm). Spawns in May – June.

Conservation status. LC. Widespread and locally abundant, but many small streams are dry in summer and populations are greatly fragmented and several potentially threatened.

Further reading. Almaça & Bănărescu, in Bănărescu & Bogutskaya, 2003: 377 (description, biology).

Luciobarbus steindachneri

Common name. Guadiana barbel.

Diagnosis. Distinguished from other species of *Barbus* and *Luciobarbus* in Iberian Peninsula by: ● in lateral view, orbit close to but not touching

Luciobarbus sclateri

Luciobarbus steindachneri

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Luciobarbus steindachneri; Guadiana drainage, Portugal; ~150 mm SL (head slightly in dorso-lateral view).

dorsal head profile / ○ last simple dorsal ray spinous, serrated posteriorly along ½–⅔ of its length / ○ 44–50 + 2–3 lateral line scales / ○ head length 26–32 % SL / ○ snout length 2.2–2.9 times in HL / ○ lower lip thick, with (70 % of individuals) or without median pad / ○ tip of lower jaw covered by lower lip / ○ dorsal head profile straight. Size up to at least 400 mm SL.

Distribution. Guadiana and Tago drainages (Spain, Portugal).

Habitat. Upper part of rivers in habitats with slow current.

Biology. Lives up to 6 years. Spawns in April – June. Feeds mainly on planktonic crustaceans, supplemented by insects and algae.

Conservation status. VU A2ce. Declining due to water abstraction and habitat modification, which favour alien species.

Remarks. Sometimes considered as adults *B. comizo* with juvenile morphology, but the differences reportedly are also distinct in juveniles and the two species differ in preferred habitat. Also suspected to be a hybrid or a species of hybrid origin.

Further reading. Almaça, 1967: 263 (description); Doadrio, 1988b: 26 (systematics); Costa Pereira, 1995: 487 (systematics); Almaça & Bănărescu, in Bănărescu & Bogutskaya, 2003: 389 (description, biology).

Key to species of *Carassius* in Europe

1a – Free edge of dorsal convex; last simple anal and dorsal rays weakly serrated; 23–33 gill rakers; 31–36 total lateral line scales; peritoneum whitish. ..... *C. carassius*

1b – Free edge of dorsal concave or straight; last simple anal and dorsal rays strongly serrated; 38–52 gill rakers; 26–33 total lateral line scales; peritoneum black. 2

2a – Golden-brown, bronze colour. ..... *C. auratus*

2b – Silvery-brown colour. ..... *C. gibelio*

Carassius auratus

Common name. Goldfish.

Diagnosis. Distinguished from other species of *Carassius* in Europe by: ○ golden-brown, bronze colour / ○ last simple anal and dorsal rays strongly serrated / ○ 38–47 gill rakers / ○ 26–31 total lateral line scales / ○ free edge of dorsal concave or straight / ○ usually 5½ branched anal rays / ○ peritoneum black. Size up to 320 mm SL.

Distribution. Reported to be native to East Asia, from Amur to Xi Jiang drainages in Russia, China, Korea and Japan, but several species apparently confused under a single name, as demonstrated by available data on Japanese populations. Domesticated in China more than 1000 years ago, introduced to Japan in 16th century and from Japan imported in Europe in 1611 (Portugal), 1691 (England) and 1755 (France). Introduced throughout Europe and most of the world. Unambiguous data on distribution in Europe are not available because it is usually confused with *C. gibelio*.

Habitat. Eutrophic, well vegetated ponds and canals. Frequently in artificial habitats.

Biology. Only diploid populations known. Spawns

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Carassius auratus; aquaculture, Germany; ~120 mm SL.

Carassius auratus; cultivated variety, wakin.
K. Yamazaki

Carassius auratus; cultivated variety, Bristol shubunkin.
K. Yamazaki

Carassius auratus; cultivated variety, red and white ryukin.
K. Yamazaki

Carassius auratus; cultivated variety, black telescope eye.
K. Yamazaki

Carassius auratus; cultivated variety, ranchu.
K. Yamazaki

Carassius auratus; cultivated variety, calico bubble eye.
K. Yamazaki

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Carassius carassius; Elbe, Germany; ~100 mm SL.

Carassius carassius; Danube drainage, Hungary; ~120 mm SL. Z. Sallai

for the first time at 1–2 years. Spawns in June – July, when temperatures reach 15–20°C. Juveniles require high temperature to grow. Individual females spawn with a few males in dense vegetation. Eggs are sticky, attached to water plants or other submerged objects. Feeds on plant material and benthic invertebrates. Usually lives up to about 20 years in artificial conditions. Omnivorous; feeds mainly on plankton, benthic invertebrates, plant material and detritus.

Conservation status. Alien.

Further reading. Kottelat, 1997: 51 (systematics); Szczerbowski, in Bănărescu & Paepke, 2002: 5 (biology).

Carassius carassius

Common name. Crucian carp.

Diagnosis. Distinguished from other species of *Carassius* in Europe by: ○ golden-green shining colour / ● last simple anal and dorsal rays weakly serrated / ● 23–33 gill rakers / ○ 31–36 total lateral line scales / ● free edge of dorsal convex /

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Carassius gibelio; Alma, Ukraine; ~120 mm SL.

● usually 6½ branched anal rays / ● peritoneum whitish. Size up to 550 mm SL.

Distribution. North, Baltic, White, Barents, Black and Caspian Sea basins; Aegean Sea basin only in Maritza drainage; eastward to Kolyma drainage (Siberia); westward to Rhine and eastern drainages of England. Absent from North Sea basin in Sweden and Norway. In Baltic basin north to about 66°N. Widely introduced to Italy, England and France but possibly often confused with *C. gibelio*.

Habitat. Usually restricted to densely vegetated backwaters and oxbows of lowland rivers. Also in small well vegetated lakes and channels. Tolerates high summer temperatures and very low oxygen concentrations in summer and under ice cover. Able to survive in almost completely frozen water or almost-dry habitats by burying itself in mud. Spawns in dense submerged vegetation.

Biology. Lives about 10 years. Males reproduce for the first time at 3 years, females at 4 years in central and eastern Europe, at 2 years in southern Europe. Spawns in May – July at temperatures above 18°C. Individual females spawn with several males. Males follow ripe females, often with much splashing. Females spawn 3–5 times during a season. Eggs are sticky and are attached to water plants. Omnivorous; feeds all day but mostly at night on plankton, benthic invertebrates, plant material and detritus. Seems to be a weak competitor, usually absent from waters with rich ichthyofauna and abundant predatory species. Very abundant in the absence of other fish species. High-bodied, fast-growing individuals in habitats with predatory fish, more elongate in habitats without predatory fish.

Conservation status. LC. Gradual but continuing extirpation in many water bodies, especially in Danube drainage and central Europe, for unknown reasons. Suspected to be due to competition with introduced *C. gibelio* in non-optimal habitats.

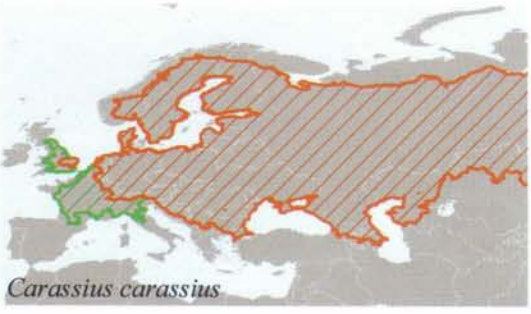
Further reading. Szczerbowski & Szczerbowski, in Bănărescu & Paepke, 2002: 43 (biology).

Carassius gibelio

Common name. Prussian carp.

Diagnosis. Distinguished from other species of *Carassius* in Europe by: ● silvery-brown colour / ○ last simple anal and dorsal rays strongly serrated / ○ 37–52 gill rakers / ○ 29–33 total lateral line scales / ○ free edge of dorsal concave or straight / ○ 5½ branched anal rays / ○ peritoneum black. Size up to 350 mm SL.

Distribution. Usually considered as native from central Europe to Siberia or introduced to European waters from eastern Asia. Unambiguous data on original distribution in Europe not available because of introduction, confusion with *C. auratus* and complex modes of reproduction. Today widespread and commonly stocked together with *Cyprinus carpio*, which is transported throughout Europe. Absent in northern Baltic basin, Iceland, Ireland, Scotland and Mediterranean islands.



Carassius carassius

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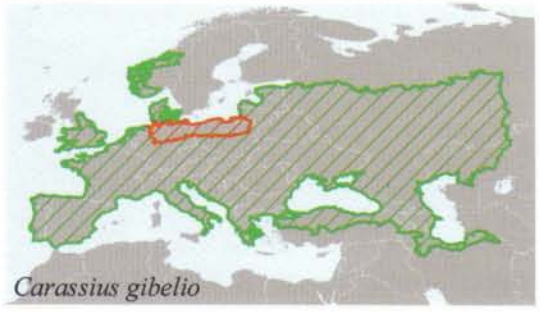
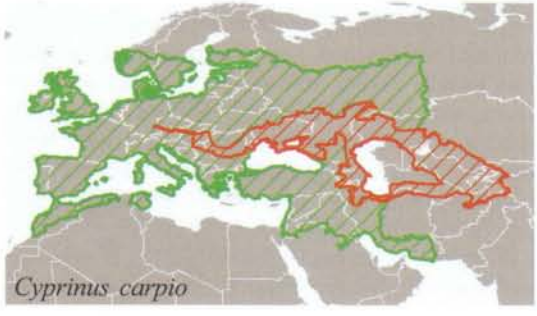
Cyprinus carpio; Caspian Sea, Iran; wild form; ~400 mm SL. A. Abdoli

Cyprinus carpio; upper Rhine, Germany; spawning. E. Korte

Habitat. A wide variety of still water bodies and lowland rivers. Very tolerant of low oxygen concentrations and pollution. Usually associated with submerged vegetation or regular flooding. Spawns on shallow, warm shores, on submerged vegetation or roots.

Biology. Some populations consist only of diploid individuals of both sexes. In other populations, there are diploid and tetraploid individuals of both sexes, often together with triploid females. There are also all-female populations in which all individuals are triploids. Triploids reproduce by gynogenesis; it remains to be demonstrated that all are conspecific. Populations of mostly diploid individuals presently seem to be abundant in Black Sea basin, spreading from lower Danube; they are





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Cyprinus carpio; aquaculture variety; ~500 mm SL. A. Hartl

Cyprinus carpio; aquaculture variety, mirror carp; ~450 mm SL. A. Hartl

invasive in many areas where they have been introduced (e.g. Crete). Triploids are sperm parasites of other cyprinid species such as *Cyprinus carpio*, *Rutilus rutilus* and *Abramis brama*. Lives about 10 years. Spawns for the first time at 3–4 years in central and eastern Europe, at 1–2 years in southern Europe. Spawns in May – July at temperatures above 14°C, spawning being most intensive early morning. Older individuals spawn earlier in season than younger ones. Males move to spawning sites before females. Individual females spawn with several males. Males follow ripe females, often with much splashing. Females spawn up to 3 times in a season. The sticky eggs are attached to water plants or other submerged objects. Feeding larvae and juveniles inhabit high-complexity habitats as reed belts. Omnivorous; feeds on plankton, benthic invertebrates plant material and detritus.

Conservation status. LC.

Remarks. Earlier treated as a wild or feral form of *C. auratus*. Genetic data show that this is not the case and suggest that, in Europe, more than one species are hidden under the name *C. gibelio*. A second triploid species, *C. langsdorfii*, from Japan, was recently found in European waters, but it does not seem to have established. At least some of the British populations identified as *C. gibelio* in fact are hybrids *C. carassius* x *C. auratus*.

Further reading. Kottelat, 1997: 52 (systematics); Vasiliev & Vasilieva, 2000 (genetics); Szczerbowski, in Bănărescu & Paepke, 2002: 5 (biology; as *C. auratus*, in part); Hänfling et al., 2005 (genetics); Kalous et al., 2007 (*C. langsdorfii*).

Cyprinus carpio

Common name. Carp.

Diagnosis. Distinguished from other species of Cyprinidae in Europe by: ● two pairs of barbels / ● 15–20½ branched dorsal rays / ● caudal deeply emarginate. Size up to 1100 mm SL and 40 kg, usually less than 400 mm SL.

Distribution. Black, Caspian and Aral Sea basins. Introduced throughout the world. Cultivated in large quantities for human food and stocked for

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Cyprinus rubrofuscus; aquaculture; 121 mm SL.

sport fishing.

Habitat. Warm, deep, slow-flowing and still waters, such as lowland rivers and large, well vegetated lakes. Semi-anadromous in Azov and Caspian basins. Introduced in all types of water bodies. Spawns along shores or in backwaters. Successful survival of larvae only in very warm water, among shallow submerged vegetation.

Biology. Males reproduce for the first time at 3–5 years, females at 4–6. Lives up to 50 years and usually spawns every year. Age of maturity is related to latitude and altitude. Spawns in May – June at temperatures above 18°C. Adults often make considerable spawning migrations to suitable backwaters and flooded meadows. Individual females spawn with a few males in dense vegetation. The sticky eggs are attached to water plants or other submerged objects. Larvae and juveniles inhabit warm and shallow flooded river margins or backwaters, feeding mostly on very small zooplankton (rotifers). Reproductive success is restricted to years when the water level starts rising in May and when high temperatures and flooding of terrestrial vegetation last for a long period during May and June. Juveniles and adults feeds on a wide variety of benthic organisms and plant material. Most active during dusk and dawn. Very tolerant of low oxygen concentrations.

Conservation status. VU A2ce. Wild populations slowly but continuously declining due to river regulation and hybridisation with domesticated stocks, East Asian congeners and their hybrids. Most likely, only very few stocks remain "genetically unpolluted" as a result of this long lasting process.

Remarks. In Europe, *C. carpio* has apparently been domesticated since the Middle Ages and cultivated stocks are assumed to be derived from the wild population of the Danube. Wild stocks occur naturally only in rivers draining to the Black, Caspian and Aral Seas. *C. carpio* is widely cultivated worldwide, but in fact many cultivated stocks (and most of the Asian ones) belong to several other East Asian species. One of them, *C. rubrofuscus* (often erroneously referred to as *C. carpio haematopterus*) is cultivated in several eastern European countries and has been introduced to Russia and Ukraine. It is not known whether it has become established there. In western Europe, Japanese ornamental varieties (kois) possibly derived from *C. rubrofuscus* or of hybrid origin occasionally escape from ponds. Wild *C. rubrofuscus* are distinguished from wild *C. carpio* by having 29–33 + 2–3 lateral line scales (vs. 33–37 + 2–3), 18–22½ branched dorsal rays (vs. 17–20½), body silvery with red pelvic, anal and lower caudal lobe (vs. grey to bronze).

Further reading. Steffens, 1958 (biology); Balon, 1974 (domestication), 1995 (domestication); Kottelat, 1997: 56 (systematics), 2001a: 22, 2001b: 45 (Asian carps); Chu & Chen, 1989: 337 (Asian carps); Zhou et al., 2004 (Asian carps).

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Subfamily Leuciscinae

Minnows

Leuciscinae are the largest subfamily of European cyprinids. They are characterised by a short dorsal fin whose last simple ray is neither serrated nor spine-like; the absence of barbels; the pharyngeal teeth usually in one or two rows; and a number of osteological characters. The subfamily is known from Europe, North Africa, northern Asia and North America; it is absent from tropical and southern Africa and tropical Asia. Leuciscines are subdivided into two tribes, the Pseudaspini including the European genera *Phoxinus* and *Rhynchocypris* and the Leuciscini including all other European genera. Pseudaspini are most diverse in East Asia and North America, while Leuciscini are more diverse in the western Palearctic where most genera are endemic. The generic systematics of Leuciscinae is still not settled. In many instances, the traditionally recognized genera are not congruent with the morphological and molecular data. This is partly due to the earlier practices to classify morphologically specialised species (for example, the single predatory species of a genus including only non-predatory species, the single small-size species of a genus including only large-size species) in their own, often monotypic genera. Also, intergeneric hybridisation and mtDNA introgression might be misleading. We adopted recent generic-level reorganisations when morphological and molecular data lead to the same conclusion.

Further reading. Bogutskaya, 1986, 1988b (osteology); Zardoya & Doadrio, 1999 (molecular phylogeny); Rüber et al., 2007 (molecular phylogeny).

Key to genera of Leuciscinae in Europe

1a – Lateral line undulated, complete; pectoral very large, reaching beyond pelvic base; belly with a sharp keel between throat and anal origin. ..... *Pelecus*

1b – Lateral line running straight or curved, or incomplete, or absent; pectoral not reaching or reaching to pelvic base; belly without a sharp keel between throat and anal origin. 2

2a – Lower lip with a cornified sheath; mouth subterminal or inferior, straight or arched (Fig. 34). 3

2b – Lower lip without a cornified sheath; mouth superior, terminal or inferior, arched. 6

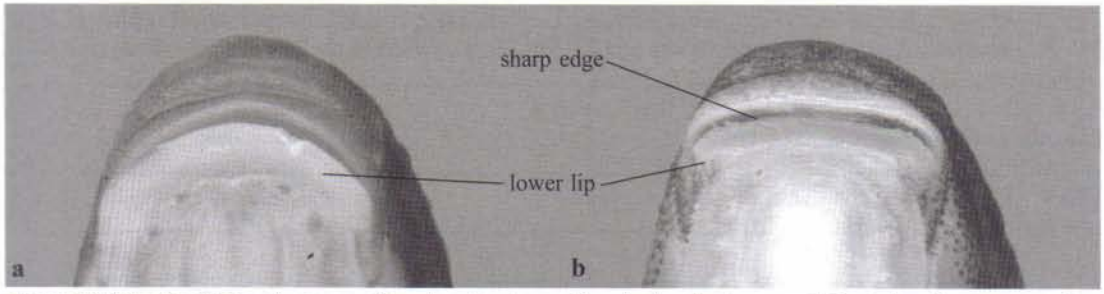

Figure 34 Mouth of *Chondrostoma*, *Parachondrostoma*, *Pseudochondrostoma* and *Protochondrostoma* species: **a,** arched, with thin cornified sheath on lower lip; **b,** straight, with thick cornified sheath on lower lip and sharp edge.

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3a – Mouth arched; 44–62 total lateral line scales; usually a dark midlateral stripe (distinct at least in preserved specimens).
..... 4

3b – Mouth straight or arched (arched only in some species of Balkan Peninsula, and in *C. duriense*, which has 63–74 total lateral line scales); no dark midlateral stripe.
..... 5

4a – Mouth strongly arched (semi-circular); Iberian Peninsula, Rhône and Garonne drainages.
..... *Parachondrostoma*

4b – Mouth slightly arched; Italy, Slovenia.
..... *Protochondrostoma*

5a – From Rhine drainage and Italy eastwards; introduced in France.
..... *Chondrostoma*

5b – Iberian Peninsula.
..... *Pseudochondrostoma*

6a – Last simple dorsal ray spinous, rigid; male with prominent pad of spongy tissue on nape.
..... *Pimephales*

6b – Last simple dorsal ray not spinous.
..... 7

7a – 84–820 gill rakers.
..... 8

7b – 6–40 gill rakers.
..... 9

8a – 84–130 gill rakers; size up to 60 mm SL; lateral line incomplete or absent, perforating 2–23 scales; 58–73 total scales in midlateral row.
..... *Anaecypris*

8b – 240–820 gill rakers; size up to 1460 mm SL; lateral line complete, 90–120 total lateral line scales.
..... *Hypophthalmichthys*

9a – A midventral keel in front of anus, exposed (scaleless) at least immediately in front of anus, usually on at least half of distance between pelvic base and anus (or keel scaled along its entire length and 48–72 + 3–5 lateral line scales).
..... 10

9b – No scaleless midventral keel in front of anus (if keel present, then it is completely scaled and 36–45 total lateral line scales).
..... 18

10a – 8–10½ branched anal rays; a conspicuous dark midlateral stripe; no longitudinal series of black spots.
..... *Tropidophoxinellus*

10b – 10–48½ branched anal rays; body silvery or plain grey; if a dark lateral stripe is present, then several longitudinal rows of spots and a small black spot on each side of each lateral line pore.
..... 11

11a – 11–23½ branched anal rays.
..... 12

11b – 23–48½ branched anal rays.
..... 17

12a – Lateral line incomplete, with only 8–12 pored scales.
..... *Leucaspius*

12b – Lateral line complete.
..... 13

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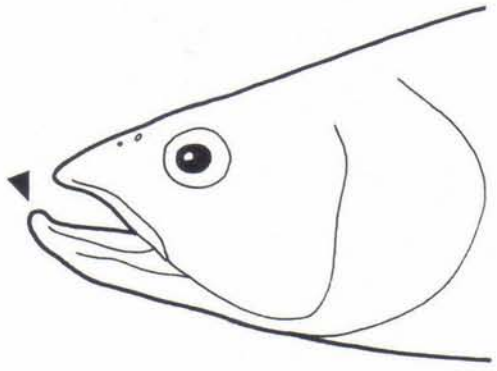

Figure 35 Symphysis of lower jaw with a conspicuous knob (arrow) fitting in a notch in upper jaw in *Aspius aspius*.

13a – Mouth large, cleft reaching beyond front margin of eye, superior; symphysis of lower jaw with a conspicuous knob fitting in a notch in upper jaw (Fig. 35); keel covered by scales. ..... *Aspius*

13b – Mouth cleft not reaching vertical of eye, superior, terminal or subterminal; symphysis of lower jaw without conspicuous know; upper jaw without median notch; keel exposed (scaleless) at least in front of anus. 14

14a – Lateral line strongly curved downward; mouth superior or terminal; size up 400 mm SL, most species less than 130 mm SL. 15

14b – Lateral line more or less along middle of flank; mouth subterminal to subinferior; size up to 700 mm SL. 16

15a – A small black spot on each side of each lateral line pore; usually a dark midlateral stripe and several longitudinal rows of spots on flank; 6–10 gill rakers, slightly longer than distance between two rakers. ..... *Alburnoides*

15b – Body silvery, without dark marks on flank, or only with a faint midlateral stripe; 13–38 gill rakers, densely set, several times longer than distance between two rakers. ..... *Alburnus*

16a – 43–46 + 2–3 lateral line scales; a scaleless dorsal groove behind nape (in adults). ..... *Blicca*

16b – 46–58 + 2–3 lateral line scales; no scaleless dorsal groove in front of dorsal. ..... *Vimba*

17a – 23–30½ branched anal rays. ..... *Abramis*

17b – 33–48½ branched anal rays. ..... *Ballerus*

18a – Body almost entirely naked, no or few scales in addition to lateral line scales. ..... *Phoxinellus*

18b – Body entirely covered by distinct scales. 19

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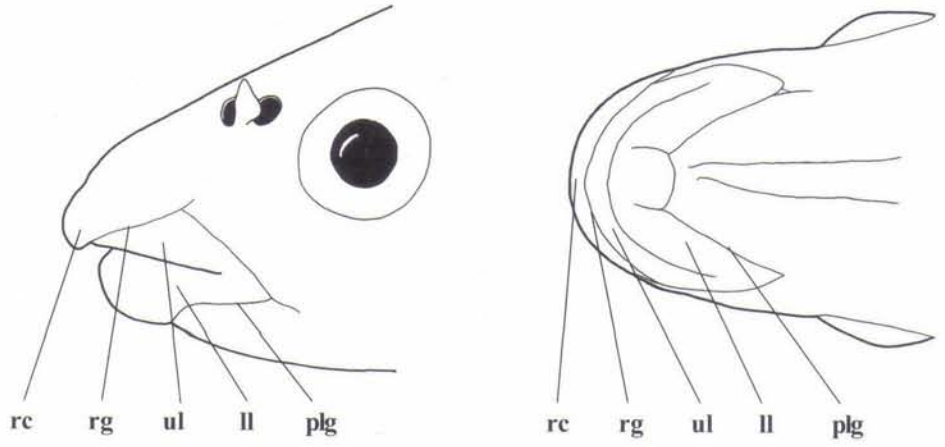

Figure 36 Lower lip with a thick median pad and rostral fold covering upper lip in *Pachychilon pictum*. **ll,** lower lip; **plg,** postlabial groove; **rc,** rostral cap; **rg,** rostral groove; **ul,** upper lip.

19a – Groove behind lower lip continuous; lower lip with two median longitudinal incisions delimitating a more or less developed median lobe (Fig. 36); part or most of anterior part of upper lip covered by fleshy overhanging rostral cap, more developed in adults (Fig. 36); 35–44 + 2 lateral line scales.
..... *Pachychilon*

19b – Groove behind lower lip interrupted medially; lower lip without median lobe; upper lip not covered by overhanging rostral cap (except in *Achondrostoma* in which the rostral cap is not fleshy and is equally developed over entire upper lip, and in some *Leuciscus*, *Iberochondrostoma* and *Telestes*, which have 43–79 + 2–3 lateral line scales).
..... 20

20a - Unbranched part of pectoral rays 1–3 thicker and stiffer in male than in female, rays 2–3 slightly slanted upward, with a conspicuous downward angle at distal end of thickened part (Fig. 38).
..... 21

20b - Pectoral fin of male not modified, identical to that of female.
..... 22

21a - Lateral line complete; female with protruding genital papilla (Croatia, Bosnia-Herzegovina).
..... *Delminichthys*

21b - Lateral line incomplete; genital papilla of female not protruding (Greece, Macedonia, Albania, Montenegro).
..... *Pelasgus*

22a - Flank with a row of dark, squarish to vertically elongated blotches, sometimes fused into an irregular midlateral stripe, followed by a separate dark spot at caudal base.
..... *Phoxinus*

22b - Body uniform silvery or yellowish brown, sometimes with a broad faint midlateral stripe or with irregular dotted or spotted pattern, no dark, squarish to vertically elongated blotches and no conspicuous dark spot at caudal base.
..... 23

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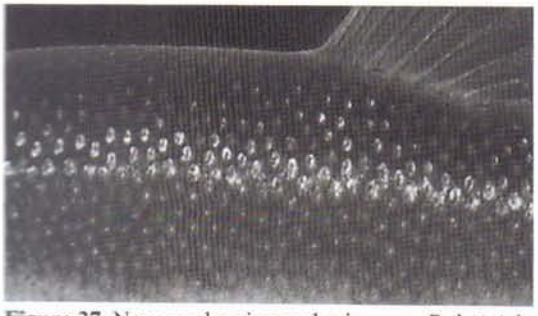

Figure 37 Non-overlapping scales in some *Delminichthys* and *Telestes* species.

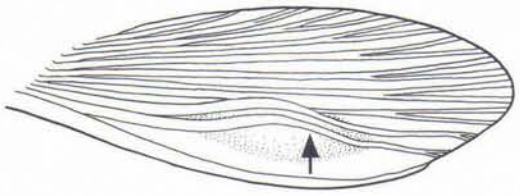

Figure 38 Modified pectoral rays in males *Delminichthys* and *Pelasgus*. Arrow points to downward angle at end of thickened section of rays.

23a - Body yellowish brown with irregular dotted or spotted pattern; scales often embedded in skin, not overlapping (Fig. 37), or rudimentary; male genital papilla with a long pointed conical projection (at least in some populations) (isolated populations in Poland, Ukraine and Russia). ..... *Rhynchocypris*

23b - Body uniform silvery or yellowish brown, sometimes with a broad faint midlateral stripe; scales usually normally developed, overlapping and not embedded in skin; males without protruding genital papilla. 24

24a - Lateral line incomplete. ..... *Ladigesocypris*

24b - Lateral line complete. 25

25a - Dorsal origin behind base of last pelvic ray; mouth superior or terminal. 26

25b - Dorsal origin above pelvic base; mouth terminal to inferior. 28

26a - A conspicuous black midlateral stripe; mouth terminal. ..... *Iberocypris*

26b - No midlateral stripe (except juvenile *Scardinius acarnanicus*, which have a conspicuously upturned mouth). 27

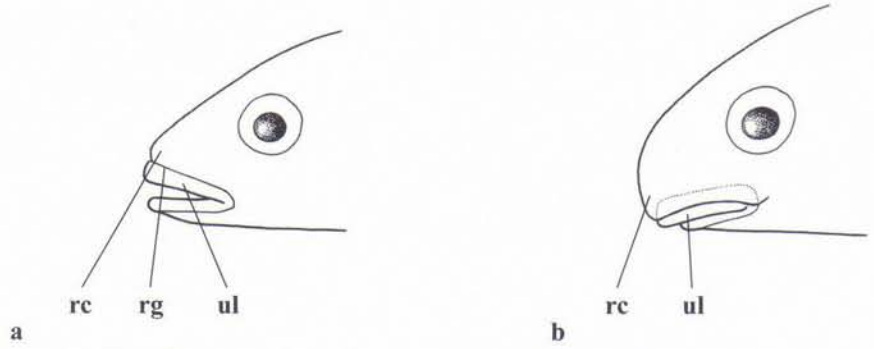

Figure 39 Position of upper lip (**ul**) and rostral cap (**rc**) in Leuciscinae. **a,** rostral cap separated from upper lip by rostral groove (**rg**); **b,** rostral cap developed as a skin covering part or whole of upper lip (after Kottelat, 2001b).

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27a - Mouth superior; keel between pelvic base and anus usually present; body depth 2.5–5.0 times in SL.
..... *Scardinius*

27b - Mouth terminal; no keel between pelvic base and anus; body depth 2.8–3.8 times in SL (some individuals of *Squalius* sp. Evia may key here; they are distinguished by 43–46 + 2–3 lateral line scales and a plain silvery body).
..... *Petroleuciscus*

28a - Rostral cap well developed, appearing as a thin skin fold covering upper half of upper lip (Fig. 39b); mouth subterminal.
..... 29

28b - Rostral cap separated from upper lip by a groove (sometimes fleshy and covering part of upper lip) (Fig. 39a); mouth terminal to inferior, terminal in most species.
..... 30

29a - Usually 30–45 + 2–3 lateral line scales.
..... *Achondrostoma*

29b - Usually 43–59 + 2–3 lateral line scales.
..... *Iberochondrostoma*

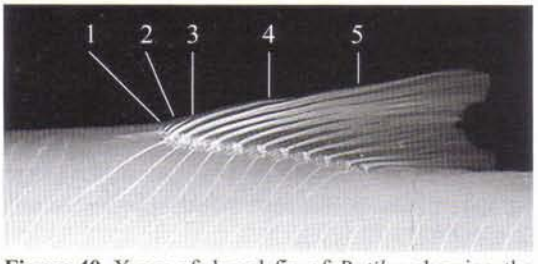

Figure 40 X-ray of dorsal fin of *Rutilus* showing the small, anterior simple rays. N. Bogutskaya

30a - Conspicuous black midlateral stripe with or without a series of small black spots on side of each lateral line pore, or a narrow dark stripe along lateral line, or almost each scale of side with a dark grey spot, often forming small stripes.
..... *Telestes* (in part)

30b - Midlateral stripe (if any) faint, brown; no small spot on each side of each lateral line pore; no narrow stripe along lateral line.
..... 31

31a - 4–5 simple dorsal rays (posterior 3 usually distinct, anterior 1–2 very short and often hidden in skin; Fig. 40); pharyngeal teeth in one row.
..... *Rutilus*

31b - 3 simple dorsal rays (posterior 2 usually distinct, anterior one very short and often hidden in skin); pharyngeal teeth in two rows.
..... 32

32a - Posterior margin of anal concave.
..... *Leuciscus*

32b - Posterior margin of anal convex or almost straight.
..... *Squalius*

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Abramis brama; upper Danube drainage, Germany; ~400 mm SL. A. Hartl

Abramis brama

Common name. Bream.

Diagnosis. Only species of genus. Distinguished from species of *Ballerus*, *Blicca* and *Vimba* by: O sub-inferior mouth, which can be extended as a tube / O 51–60 total lateral line scales / O 23–30½ branched anal rays / O eye small, diameter about ⅔ of snout length in individuals larger than 100 mm SL / O pharyngeal teeth 5–5 / O base of paired fins hyaline or grey. Size up to 700 mm SL.

Distribution. Most European drainages, from Adour (France) to Pechora (White Sea basin); Aegean Sea basin, in Lake Volvi and Struma and Maritza drainages. Naturally absent from Iberian Peninsula, Adriatic basin, Italy, Scotland, Scandinavia north of Bergen (Norway) and 67°N (Finland). Locally introduced in Ireland, Spain and northeastern Italy. In Asia, Marmara basin (Turkey) and eastward to Aral basin. Introduced in Lake Baikal and upper Ob and Yenisei drainages.

Habitat. A wide variety of lakes and large to medium sized rivers. Most abundant in backwaters, lower reaches of slow-flowing rivers, brackish estuaries and warm and shallow lakes. Semi-anadromous individuals enter freshened parts of seas to forage. Usually spawns in densely vegetated backwaters, floodplains or lake shores. Sometimes far from shore. Nearly all surfaces can be used for spawning.

Biology. Gregarious. During winter, forms large aggregations, often together with other fish. Lives about 10–20 years. Spawns for the first time at 3–4 years. Some females do not spawn every year. Spawns in May – June at temperatures above 15°C. In many populations, spawning migration starts in autumn (especially semi-anadromous individuals), slows down during winter and continues in spring. Migrate far upriver (100 km in Dniepr) to spawn. Males with nuptial tubercles on head and

Abramis brama; Rhine drainage, Germany; nuptial male, ~550 mm SL.

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body. Males often defend spawning territories along shoreline. Females spawn from once a year over a few days (Rhine) to 1–3 portions, at 7–14 days intervals (Lake Ilmen). Eggs are sticky and egg size increases with age of female. Larvae and juveniles inhabit still water bodies, feeding on plankton. Survival of juvenile is high in backwaters and low in main channel of large rivers. Growth is faster in main river than in backwaters. Juveniles 1–2 years old move from backwaters to river for feeding. If juveniles do not have an opportunity to leave backwaters, they are able to adapt but have a slower growth and reach maturity at a smaller size (stunted populations). In lower parts of large rivers, juveniles drift to brackish estuaries to forage when water level of flooded areas drops. Juveniles that forage in brackish waters enter lower parts of rivers to overwinter in freshwater. Juveniles mostly feed on zooplankton. Feeds on benthic invertebrates, which are dug out of fine bottom sediments, and also often on molluscs. May shift to particle feeding or even filter feeding at high zooplankton abundance. Frequently forms fertile hybrids with *Rutilus rutilus*.

Conservation status. LC.

Remarks. Other breams traditionally included in *Abramis* are now placed in *Ballerus*, *Blicca* and *Vimba*.

Further reading. Berg, 1949: 768 (biology); Molls, 1999 (biology); Brylińska & Boroń, 2004 (biology).

Achondrostoma

This genus in endemic to the Iberian Peninsula. The species were earlier placed in *Chondrostoma* (see comments under this genus). They have a small size, a small mouth, without cornified sheath on lower lip, and inhabit slow flowing stretches of streams. The published diagnoses of several species do not efficiently differentiate them and the following key is tentative.

Key to species of *Achondrostoma*

1a – Usually 30–38 + 2–3 lateral line scales; 11–12 scales rows around caudal peduncle; eye diameter smaller than snout length; ventral profile of head with a marked angle at articulation of lower jaw. ..... *A. oligolepis*

1b – Usually 37–45 + 3 lateral line scales; 14 scales rows around caudal peduncle; eye diameter equal to or greater than snout length; ventral profile of head without marked angle at articulation of lower jaw. 2

2a – Usually 3 scale rows between lateral line and pelvic base; snout pointed, conical. ..... *A. occidentale*

2b – 4–5 scale rows between lateral line and pelvic base; snout rounded, obtuse. ..... *A. arcasii*

Achondrostoma arcasii

Common name. Bermejuela.

Diagnosis. Distinguished from other species of *Achondrostoma* by: ● usually 40–45 + 3 lateral line scales / ● 4–5 scale rows between lateral line and pelvic origin / ● 14 scale rows around caudal peduncle / ● eye diameter equal to or greater than snout length / ● ventral profile of head without marked angle at articulation of lower jaw / ● snout rounded, obtuse. Size up to 104 mm SL.

Distribution. Spain and Portugal, most drainages from Jucar northward and headwaters of Tagus, except northern slope. Introduced in Guadiana drainage.

Habitat. In streams and reservoirs in hilly areas.

Biology. Spawns at 2 years, in May – June. Juveniles inhabit shallow areas with slow current, move to deeper and faster waters by late July. Feeds opportunistically, but mainly on aquatic invertebrates.

Conservation status. VU A3ce.

Further reading. Collares-Pereira, 1979 (description); Doadrio, 2001: 167 (biology).

Achondrostoma occidentale

Common name. Western ruivaco.

Diagnosis. Distinguished from other species of *Achondrostoma* by: ● usually 37–41 + 2–3 lateral line scales / ● 3–4 (modally 3) scale rows between lateral line and pelvic base / ● 14 scale rows around caudal peduncle / ● eye diameter greater than snout length / ● ventral profile of head with-

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Achondrostoma arcasii; Ebro drainage, Spain; ~100 mm SL.

Achondrostoma occidentale; Sizandro, Portugal; ~90 mm SL.

out marked angle at articulation of lower jaw / ○ snout usually pointed, conical. Size up to at least 95 mm SL.

Distribution. Portugal: Estremadura, in Alcabrichel, Sizandro and Safarujo drainages.

Habitat. Lower stretches of rivers.

Biology. No data. Spawns in April – May.

Conservation status. EN B1ab(iii) + 2ab(iii). Very small range, sharply declining because of pollution, intensive agriculture and water extraction.

Further reading. Robalo et al., 2005b: 23 (diagnosis).

Achondrostoma oligolepis

Common name. Ruivaco.

Diagnosis. Distinguished from other species of *Achondrostoma* by: ○ usually 30–38 + 2–3 lateral line scales / ○ 3–4 (usually 3) scale rows between lateral line and pelvic base / ● 11–12 scale rows around caudal peduncle / ○ eye diameter smaller than snout length / ● ventral profile of head with a marked angle at articulation of lower jaw / ○ snout rounded, obtuse. Size up to about 150 mm SL.

Distribution. Portugal: from Limia to Tornada drainages (south of Douro).

Achondrostoma arcasii

Achondrostoma occidentale

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Achondrostoma oligolepis; Pecho Morel, Portugal; ~80 mm SL.

Habitat. Lower stretches of rivers.
Biology. No data.
Conservation status. LC, but several populations declined sharply due to habitat degradation, sand extraction and pollution.
Further reading. Collares-Pereira, 1979 (description; as *Rutilus macrolepidotus*); Robalo et al., 2005a: 47 (nomenclature).

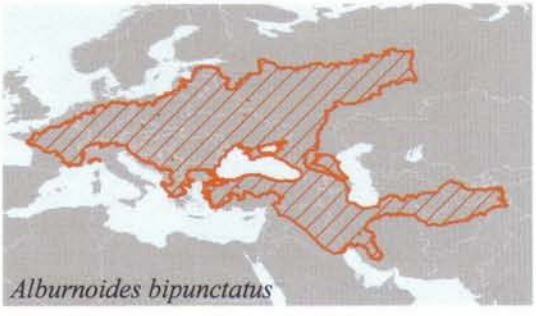
Alburnoides

Alburnoides are small-sized fishes, which inhabit fast flowing waters and the surf zone of lakes. *Alburnoides* are sometimes difficult to distinguish from *Alburnus*, but the two genera do not seem to be closely related. While clearly distinct in preserved individuals, the small black spots on each side of each lateral line pore and the dark grey stripe are often invisible in life. The orange base of the pectoral, pelvic and anal fins help to immediately distinguish them from small *Alburnus* in the field. The genus *Alburnoides* is widespread from France to Afganistan and it seems that the number of included species is much underestimated. We recognise three species, but, although the morphological differences appear slight, there are indications from molecular studies that *Alburnoides* from Montenegro, Greece, Bulgaria, Crimea and Caucasus most likely represent distinct species.

Key to species of *Alburnoides* in Europe

1a – Mouth turned upward; dorsal profile with a marked concavity at nape; caudal peduncle 1.6–1.8 times longer than deep (Lake Ohrid). ..... *A. ohridanus*

1b – Mouth terminal, only slightly slanted; dorsal profile regularly convex; caudal peduncle 1.8–2.3 times longer than deep. 2



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Alburnoides bipunctatus; Danube drainage, Germany, ~85 mm SL. A. Hartl

2a – 10–11½ branched anal rays; snout longer than eye diameter; interorbital distance 1.2–1.4 times eye diameter; 40–43 + 2–3 lateral line scales (Lakes Prespa). ..... *A. prespensis*

2b – 12–17½ branched anal rays; snout length equal to or smaller than eye diameter; interorbital distance about equal to eye diameter; 44–50 + 2–3 lateral line scales. ..... *A. bipunctatus*

Alburnoides bipunctatus

Common name. Spirlin.

Diagnosis. Distinguished from other species of *Alburnoides* in Europe by: ○ mouth terminal / ○ 12–17½ branched anal rays / ○ snout length equal to or smaller than eye diameter / ○ eye diameter about equal to interorbital distance. Differences between geographically distinct populations suggest that more than one species might be involved. Size up to about 130 mm SL.

Distribution. From Loire drainage (France) eastward, in nearly all rivers draining to southern Baltic, North, Black and Azov Seas; Caspian basin, in upper Volga and from Kura drainage southward to Iranian tributaries of Caspian; widespread in Iran. In Mediterranean basin, only in Rhône and some small coastal drainages from Provence (France) eastward to Genova (Italy), Aoos (Greece, Albania) and western Greece as far south as Sperchios drainage. In Marmara basin, western Anatolia south to Great Menderes drainage and in upper Euphrat and Tigris drainages. Aral basin, upper Amu Darja and Karakumskij drainages (Turkmenistan, Afghanistan).

Habitat. Streams and rivers in foothills, with well oxygenated, fast-flowing water. Spawns on gravel in swift current.

Biology. Spawns for the first time at 2 years and usually only 1 or 2 seasons. Spawns in May – July, when temperature rises above 12°C. Females spawn more than once during a season. Spawns in small groups and deposit eggs deep into gravel. Juveniles in a wide variety of shoreline habitats. All age classes inhabit open water of streams and small rivers. Feeds on terrestrial and drifting invertebrates.

Conservation status. LC. Widespread and regionally abundant. Locally threatened due to stream regulation, stocking of trout and pollution.

Further reading. Zardoya & Doadrio, 1999 (genetics); Bless, 1994 (reproduction).

Alburnoides ohridanus

Common name. Ohrid spirlin.

Diagnosis. Distinguished from other species of *Alburnoides* in Europe by: ● marked concavity at nape, mouth distinctly upturned / ○ 11½ branched anal rays / ○ 42–44 + 2–3 lateral line scales / ○ caudal peduncle 1.6–1.8 times longer than deep / ○ snout length equal to eye diameter / ○ interorbital distance about equal to eye diameter. Size up to about 90 mm SL.

Alburnoides ohridanus

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Alburnoides ohridianus; Lake Ohrid, Macedonia; ~74 mm SL.

Alburnoides prespensis; Lake Prespa, Greece; ~89 mm SL.

Distribution. Lake Ohrid (Macedonia, Albania).
Habitat. Surf zone along lake shores.
Biology. Spawns in May – June.
Conservation status. VU D2.
Further reading. Karaman, 1928: 153 (description).

Alburnoides prespensis

Common name. Prespa spirlin.
Diagnosis. Distinguished from other species of *Alburnoides* in Europe by: ○ mouth terminal, cleft only slightly slanted / ○ 10–11½ branched anal rays / ○ 40–43 + 2–3 lateral line scales / ○ caudal peduncle 1.8–2.2 times longer than deep / ● snout longer than eye diameter / ● interorbital distance 1.2–1.4 times eye diameter. Size up to about 90 mm SL.
Distribution. Lakes Prespa (Greece, Macedonia, Albania).
Habitat. Surf zone along lake shores.
Biology. Spawns in May – June.
Conservation status. VU D2.
Further reading. Karaman, 1924: 54 (description).

Alburnoides bipunctatus; spawning; Rhine drainage, Germany, ~80 mm SL. R. Bless

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Alburnus

The present genus *Alburnus* includes species, which have traditionally been placed in two distinct genera, *Alburnus* (bleaks) and *Chalcalburnus* (shemayas). The earlier distinction between the two genera was based on the ventral keel not or partly scaled, the number and size of gill-rakers and the degree of serration of the pharyngeal teeth. These characters show variability and overlap in several species of the two groups as well as within some species, and have no diagnostic value at genus level. The length of the exposed (scaleless) part of the ventral keel is measured as the number of transverse scale rows along the exposed part of the keel, counted from anus forwards (Fig. 41). The relative lengths of gill rakers and gill filaments are used to diagnose some species; they are measured on the gill raker at the angle between the upper and lower limbs of the first gill arch and on the opposite inner gill filament (Fig. 42). *Alburnus alburnus* and *A. chalcoides* were earlier composed of a number of subspecies. Examination of material for this study showed that a number of them are valid species.

Further reading. Freyhof & Kottelat, 2007a-b (systematics).

Key to species of *Alburnus* in Europe

Atlantic, Western Mediterranean and Adriatic basins

1a – 47–58 + 3 lateral line scales. 2

1b – 39–48 + 3 lateral line scales. 3

2a – 30–38 gill rakers; ventral keel exposed for 2–5 scales in front of anus; 48–58 + 3 lateral line scales (Lakes Prespa). ..... *A. belvica*

2b – 17–22 gill rakers; ventral keel scaless or exposed for at least ⅔ of distance from anus to pelvic base; 47–53 + 3 lateral line scales (Drin drainage). ..... *A. scoranza*

3a – 17–20½ branched anal rays; no dark midlateral stripe in life; 45–48 + 3 lateral line scales (Europe north of Pyrénées, Alps and Caucasus). ..... *A. alburnus*

3b – 11–16½ branched anal rays; a faint midlateral stripe in life; 39–47 + 3 lateral line scales. 4

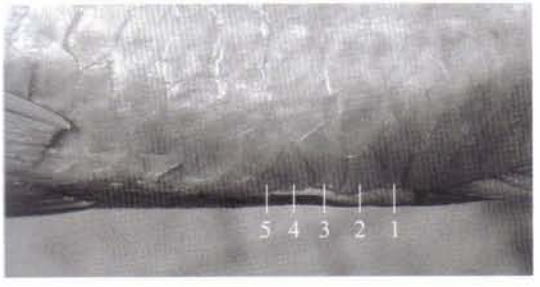

Figure 41 Ventro-lateral view of *an Alburnus* species showing how scales are counted along scaleless part of ventral keel.

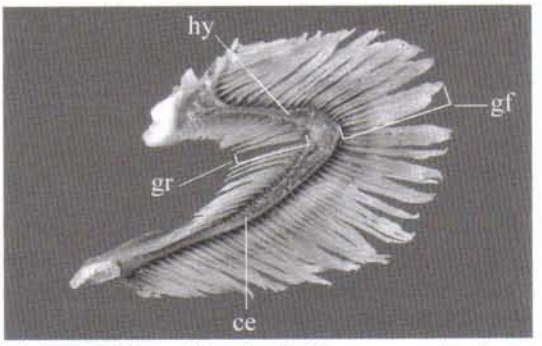

Figure 42 First gill arch of *Alburnus* species, inner view, showing the gill raker (**gr**) and gill filament (**gf**) used for calculating ratios. **hy,** upper limb (hypobranchial); **ce,** lower limb (ceratobranchial).

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4b – 13–16½ branched anal rays; very contrasted dark midlateral stripe when preserved; 16–22 gill rakers; anal origin below base of branched dorsal rays 4–8 (Adriatic basin).
..... *A. arborella*

4b – 11–13½ branched anal rays; faint dark midlateral stripe when preserved; 13–18 gill rakers; anal origin below or behind base of last dorsal ray (southern Italy).
..... *A. albidus*

Aegean, Black and Caspian Seas

1a – Anal origin behind base of dorsal or below base of last dorsal ray; if below base of last ray, then 54–69 + 4 lateral line scales.
..... 2

1b – Anal origin below base of branched dorsal rays 4–6.
..... 12

2a – 17–20½ branched anal rays.
..... *A. danubicus*

2b – 13–17½ branched anal rays.
..... 3

3a – 24–35 gill rakers; numerous small tubercles in nuptial males.
..... 4

3b – 18–27 gill rakers; few, large tubercles in nuptial males (small tubercles only in *A. mento*).
..... 8

4a – Length of gill raker at angle of upper and lower limbs of first gill arch 60–90 % of opposite inner gill filament (Lakes Volvi and Koronia).
..... *A. volviticus*

4b – Length of gill raker at angle of upper and lower limbs of first gill arch 30–55 % of opposite inner gill filament.
..... 5

5a – Anal origin about 1½–2½ scales behind dorsal base; 15–17½ branched anal rays; up to 310 mm SL.
..... 6

5b – Anal origin ½–1½ scales behind dorsal base; 13–15½ branched anal rays; up to 206 mm SL.
..... 7

6a – 27–34 gill rakers (Black Sea basin).
..... *A. sarmaticus*

6b – 24–28 gill rakers (Azov Sea basin).
..... *A. leobergi*

7a – Caudal peduncle depth 8–10 % SL; ventral keel exposed for 8–12 scales in front of anus; base of paired fins hyaline or grey in spawning adults (Thrace).
..... *A. istanbulensis*

7b – Caudal peduncle depth 10–11 % SL; ventral keel exposed for 6–8 scales in front of anus; base of paired fins orange in spawning adults (Lake Mandras).
..... *A. mandrensis*

8a – Caudal peduncle depth 1.7–1.9 times in its length (Crimea).
..... *A. mentoides*

8b – Caudal peduncle depth 1.8–3.0 times in its length.
..... 9

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9a – Anal origin about ½–1½ scales behind base of dorsal (Lake Vistonis).
..... *A. vistonicus*

9b – Anal origin about 1½–2½ scales behind base of dorsal.
..... 10

10a – 15–17½ branched anal rays; length of caudal peduncle 16-19 % SL (upper Danube drainage).
..... *A. mento*

10b – 13–15½ branched anal rays; length of caudal peduncle 18-21 % SL.
..... 11

11a – 63–67 + 4 lateral line scales; head length 22–26 % SL; 21–27 gill rakers; predorsal length 55–58 % SL (Resovska and Veleka drainages).
..... *A. schischkovi*

11b – 54–65 + 4–5 lateral line scales; head length 20–24 % SL; 18–23 gill rakers; predorsal length 52–56 % SL (Caspian basin).
..... *A. chalcoides*

12a – 17–20½ branched anal rays.
..... *A. alburnus*

12b – Usually 11–16½ branched anal rays (17½ in some *A. thessalicus*).
..... 13

13a – 24–32 gill rakers (Lakes Volvi and Koronia, Rivers Vardar and lower Strymon).
..... *A.* sp. Volvi

13b – 16–26 gill rakers.
..... 14

14a – Depth of caudal peduncle 2.2–2.8 times in its length; 45–55 + 2–3 lateral line scales; pectoral reaching pelvic base (Lake Doiran).
..... *A. macedonicus*

14b – Depth of caudal peduncle 1.7–2.1 times in its length; 38–49 + 2–3 lateral line scales; pectoral not reaching pelvic base.
..... 15

15a – 38–43 + 3 lateral line scales; body depth 25–32 % SL (western Caspian drainages).
..... *A. hohenackeri*

15b – 42–49 + 2–3 lateral line scales; body depth 21–24 % SL (Aegean basin).
..... *A. thessalicus*

Alburnus albidus

Common name. Vulturino.

Diagnosis. Distinguished from other species of *Alburnus* in the Apennine and Balkan peninsulas by: ● anal origin immediately behind or below last branched dorsal ray / ● 39–45 + 3 lateral line scales / ● 11–13½ branched anal rays / ● 13–18 gill rakers / ● ventral keel exposed from anus to pelvic base / ● faint dark lateral stripe when preserved / ● pectoral reaching pelvic base / ● mouth terminal. Size up to 110 mm SL.

Distribution. Southern Italy: from Trigno to Basento drainages (Adriatic basin), from Volturno to Alento drainages (Tyrrhenian basin). Introduced in several southern Italian drainages.

Habitat. Well oxygenated, clear montane and hilly streams and small rivers.

Biology. Spawns for the first time at 1–2 years. Usually spawns only for a single season. Spawns in May – August at temperatures above 15°C. Feeds on drifting insects or invertebrates fallen on waters surface.

Conservation status. VU B2ab(i,ii,iii,iv,v). Very small range; threatened by pollution, impoundment

Alburnus albidus

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Alburnus albidus; Trigno, Italy; ~80 mm SL.

Alburnus alburnus; Elbe drainage, Germany; ~100 mm SL.

of streams and invasion by non-native species.
Further reading. Bianco, 1978 (description), 1980: 33 (systematics).

Alburnus alburnus

Common name. Bleak.
Diagnosis. Distinguished from other species of *Alburnus* in Europe by: **O** anal origin below branched dorsal rays 4–5 / **O** 45-48 + 3 lateral line scales / **O** 17–20½ branched anal rays / **O** 16–22 gill rakers / **O** ventral keel exposed from anus to pelvic base / **O** lateral stripe absent in life, faint or absent in preserved individuals / **O** mouth slightly superior. Size up to 160 mm SL.
Distribution. Most of Europe north of Caucasus, Pyrénées and Alps, eastward to Ural and Emba. Naturally absent from Iberian Peninsula, Adriatic and Aegean basins (except Maritza drainage), Italy, Ireland, Great Britain (except southeast), Norway and Scandinavia north of 67°N, Caspian basin south of Volga. In Anatolia: Marmara basin. Locally introduced in Spain, Portugal and Italy.
Habitat. Open waters of lakes and medium to large rivers. Forages close to surface. In winter forms large aggregations in backwaters and other still waters. Spawns in shallow riffles or along stony shores of lakes, occasionally above submerged vegetation.
Biology. Gregarious. Spawns for the first time at 2–3 years. Usually spawns only one or two seasons. Spawns in May – August at temperatures above 12°C, 2–4 times at 1–2 week intervals, ear-

Alburnus alburnus

Alburnus arborella

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Alburnus arborella; Lake Garda, Italy; ~70 mm SL.

Alburnus belvica; Lake Prespa, Greece; 107 mm SL.

ly morning. Larvae inhabit littoral zone of rivers and lakes, juveniles leave shores and occupy a pelagic habitat, feeding on plankton, drifting insects or invertebrates fallen on the water surface. Scales were earlier used to make Essence d'Orient, a coating for artificial pearls.

Conservation status. LC.

Further reading. Biro & Musko, 1995 (biology).

Alburnus arborella

Common name. Alborella.

Diagnosis. Distinguished from other species of *Alburnus* in the Adriatic basin by: ○ anal origin below branched dorsal rays 4–8 / ○ 40-47 + 3 lateral line scales / ○ 13–16½ branched anal rays / ○ 16–22 gill rakers / ○ ventral keel exposed or partly or completely scaled / ○ lateral stripe faint in life, very prominent in preserved individuals / ○ pectoral not reaching pelvic base / ○ mouth slightly superior. Size up to 100 mm SL.

Distribution. Adriatic basin: from Soca drainage to Ancona province (Slovenia, Switzerland, Italy), lower Zrmanja and Neretva drainages (Croatia, Bosnia-Herzegovina). Tyrrhenian basin: Arno drainage (Italy). Introduced in Ricica (Croatia), Ombrone and Tevere drainages (Italy).

Habitat. Open surface waters in a variety of habitats ranging from large subalpine lakes to small, lowland streams. Spawns in shallow riffles or along stony shores of lakes, occasionally above submerged vegetation.

Biology. Spawns for the first time at 1–2 years. Usually spawns only for a single season, in May – August at temperatures above 15°C. Feeds on plankton, drifting insects or invertebrates fallen on waters surface.

Conservation status. LC.

Remarks. *A. alborella* is a frequently used incorrect spelling.

Further reading. Bianco, 1980: 36 (as *A. alburnus alborella*; systematics); Kottelat & Bianco, 2005 (nomenclature).

Alburnus belvica

Common name. Prespa bleak.

Diagnosis. Distinguished from other species of *Alburnus* in Europe by: ● 30–38 gill rakers / ○ anal origin about 1–2½ scales behind base of last dorsal ray / ○ 48–58 + 3 scales along lateral line / ○ 12–15½ branched anal rays / ○ ventral keel exposed for 2–5 scales in front of anus / ○ depth of caudal peduncle depth 2.0–2.1 times in its length. Size up to about 160 mm SL.

Distribution. Lakes Prespa (Greece, Macedonia, Albania).

Habitat. Lacustrine, spawns in tributaries and along shores on pebbles and gravel in surf zone.

Biology. Migrates to spawning sites in tributaries

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Alburnus chalcoides; Samur, Russia; ~120 mm SL. A. Naseka

at night. Spawns in June, on days without waves, within centimetres of shoreline, in small groups. Forms large schools while foraging. Main prey of breeding Dalmatian pelicans (*Pelecanus crispus*). Feeds on plankton.

Conservation status. VU D2.

Further reading. Economidis, 1986 (description); Dimovski & Grupče, 1972 (morphology); Pyrovetsi & Economidis, 1998: 9 (predation).

Alburnus chalcoides

Common name. Caspian shemaya.

Diagnosis. Distinguished from other species of *Alburnus* in Caspian and Black Sea basins by: ○ anal origin about 1½–2½ scales behind last branched dorsal ray / ○ 54–65 + 4–5 lateral line scales / ○ 13–15½ branched anal rays / ○ 18–23 gill rakers / ○ ventral keel exposed for 8–12 scales in front of anus (up to almost 80 % of distance between anus and pelvic base) / ○ head length 20–24 % SL / ○ predorsal length 52–56 % SL / ○ depth of caudal peduncle 1.9–2.4 times in its length / ○ few, large tubercles in nuptial males / ○ no dark midlateral stripe. Size up to 400 mm SL.

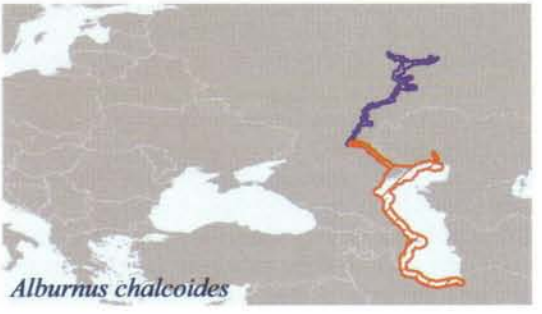
Distribution. Caspian (mostly western to southen coast, rarely in Ural and Volga. Populations from Aral Sea basin might belong to this species.

Habitat. Lower parts of rivers, coastal lakes, estuaries, and brackish areas of sea. Lives close to surface and tolerates salinities up to 14 ‰. Earlier migrated for long distances upstream, up to upper reaches of streams in piedmont and montane zones. Spawns in small rivers or streams with heavy current on gravel bottom. Landlocked populations in reservoirs spawn in reservoir tributaries.

Biology. Semi-anadromous and landlocked populations. Spawns for the first time at 2–4 years, females 1 year later than males. Anadromous populations start entering rivers in autumn (September in Kura) and move upstream during winter and/or in spring. Spawns in May – September in water 0.2–0.7 m deep, current about 1 m/s, and 18–26°C, often with much splashing. Males seem to be partly territorial. Males assemble at spawning grounds and wait for ripe females, which arrive later. Eggs are sticky and adhere on pebbles or stones. Embryonic development lasts 2–3 days, larvae first staying among gravel for 8–11 days, then actively migrating to shallows and backwaters. Adults migrate back to sea, lakes or estuaries soon after spawning to forage. Young juveniles migrate downriver in autumn of same year or next spring. Larvae and young juveniles feed on zooplankton, algae and insect larvae, adults mainly on planktonic crustaceans, terrestrial insects, and small fish.

Conservation status. LC. Almost all long-distance migrating populations lost as they were no longer able to reach spawning sites because of dams. Survives in small water courses and as landlocked populations in some reservoirs. Expected to be declining and to further decline because of expanding hydroelectric development and strong ecological impacts on Caspian Sea.

Remarks. A morphologically variable species. This variability has usually been considered to be



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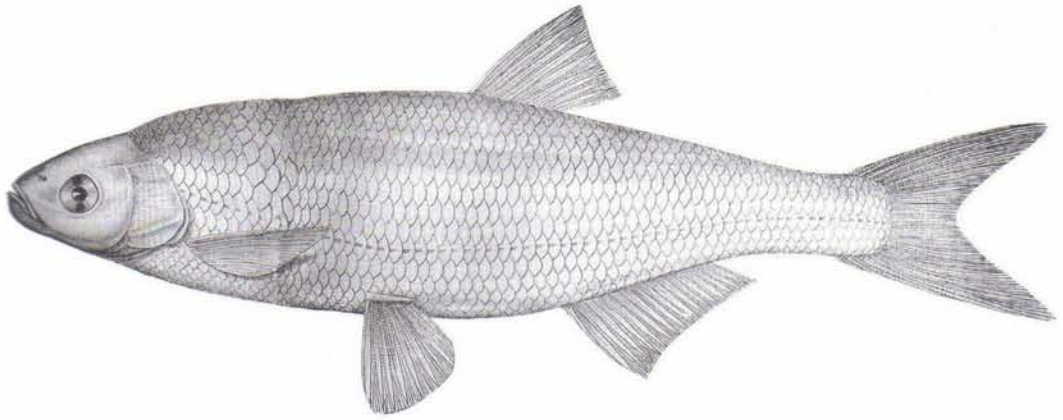

Alburnus danubicus; lower Danube, Romania (original image distorted behind pectoral). (from Antipa, 1909)

an adaptation to different habitats, but our data suggest that this is probably due to several species being confused under the name *A. chalcoides*.
Further reading. Bănărescu, 1961 (systematics); Movchan & Smirnov, 1983: 7 (morphology, biology); Kazancheyev, 1981: 66 (Caspian Sea).

Alburnus danubicus

Common name. Danube shemaya.
Diagnosis. Distinguished from other species of *Alburnus* in Black Sea basins by: ○ anal origin about 1½–2½ scales behind base of last dorsal ray / ○ 63–64 + 4 lateral line scales / ○ 17–20½ branched anal rays. Size up to about 200 mm SL.
Distribution. Lower Danube in Romania and Bulgaria.
Habitat. Main river and coastal lakes.
Biology. No data.
Conservation status. Extinct*. Known only from two records in 1909 and 1943.
Remarks. Published morphological data suggest that two species of shemayas were possibly present in the lower Danube until about 1940. One of them (*A. danubicus*) had a much higher anal ray count than the other (*A. sarmaticus*); it is extinct and there is no museum material on which to check its validity.
Further reading. Antipa, 1909: 162 (description); Drensky, 1943: 359 (description); Freyhof & Kottelat, 2007a (identity).

Alburnus hohenackeri

Common name. Caucasian bleak.
Diagnosis. Distinguished from other species of *Alburnus* in Caspian and Black Sea basins by: ○ anal origin below branched dorsal rays 4–5 / ○ 38–43 + 3 lateral line scales / ○ 11–16½ branched anal rays / ○ 16–25 gill rakers / ○ ventral keel exposed or partly or completely scaled / ○ body deep, depth 25–32 % SL, markedly laterally compressed / ○ depth of caudal peduncle 1.7–2.1 times in its length. Size up to 150 mm SL.
Distribution. Western and southern Caspian basin, from Kuma to Artek drainages.
Habitat. Water bodies with slow to fast current; prefers places where current is slowed down. Abundant in middle and lower reaches of large rivers and their tributaries, reservoirs and swampy creeks; also in brackish water at river mouths, in estuaries and coastal lakes. Spawns in shallow water, 0.1–0.5 m deep.
Biology. Pelagic, commonly forms schools in upper water layers. Lives up to 3 years, spawns 1–2 times during its life. Spawns in April – July, when temperatures rise above 18–23°C. Eggs sticky, laid on submersed plants, rarely on pebbles, 1.4 mm

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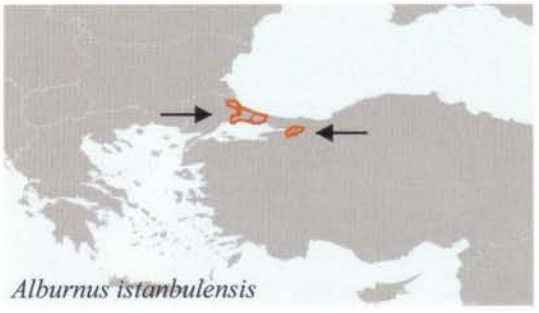
Alburnus hohenackeri; Samur, Russia; ~70 mm SL. A. Naseka

Alburnus istanbulensis; Büyükçekmece Reservoir, Turkey; ~130 mm SL. M. Özuluğ

diameter. Females lay 2–3 portions of eggs in a season. Feeds on plankton, insect larvae, seeds.
Conservation status. LC.
Further reading. Berg, 1949: 749 (description; as *A. charusini*).

Alburnus istanbulensis

Common name. Thracian shemaya.
Diagnosis. Distinguished from other species of *Alburnus* in Aegean and Black Sea basins by: ○ anal origin about ½–1½ scales behind dorsal base / ○ 57–63 + 3–4 lateral line scales / ○ 13–15½ (mode 14½) branched anal rays / ○ base of paired fins hyaline or grey in spawners / ○ 24–35 (mode 31) gill rakers / ○ length of gill raker at angle of upper and lower limbs of first gill arch 30–55 % of opposite inner gill filament / ○ ventral keel exposed for 8–12 scales in front of anus / ○ depth of caudal peduncle / ○ few, large tubercles in nuptial males 1.8–2.3 times in its length. Size up to 180 mm SL.
Distribution. Coastal streams of Thrace from Karasu (Sea of Marmara basin) to Papuc (Black Sea basin) (Turkey).
Habitat. Riverine and lacustrine. Migrates to upper reaches of tributaries to spawn. Spawns in riffles with heavy current on gravel bottom.
Biology. Forages in lower part of rivers, close to surface.
Conservation status. LC.
Further reading. Battalgil, 1941: 179 (description); Özuluğ & Freyhof, 2007 (description).



Alburnus istanbulensis

Alburnus leobergi

Common name. Azov shemaya.
Diagnosis. Distinguished from other species of *Alburnus* in Black Sea basin by: ○ anal origin about 1½–2½ scale behind dorsal base / ○ 54–64 + 4–5 lateral line scales / ○ 15–17½ branched anal rays / ○ 24–28 gill rakers / ○ length of gill raker at angle of upper and lower limbs of first gill arch 30–50 % of opposite inner gill filament / ○ ven-

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Alburnus leobergi; Obitochnaya, Ukraine; 144 mm SL.

Alburnus macedonicus; Lake Doiran, Greece; ~100 mm SL.

tral keel exposed for 4–6 scales in front of anus / ○ depth of caudal peduncle 1.7–2.0 times in its length / ○ in adult spawners, base of paired fins grey / ○ numerous small tubercles in nuptial males. Size up to 310 mm SL.

Distribution. Sea of Azov basin (Russia, Ukraine). Landlocked population in Tsimlyansk Reservoir (Don drainage).

Habitat. Lower parts of rivers, coastal lakes, estuaries, and open sea. At sea, lives close to surface and tolerates salinities up to 12 ‰. Landlocked populations in reservoirs. Migrates for long distances, up to upper reaches of streams in piedmont and montane zones. Spawns in rivers or streams with heavy current, on gravel bottom. Landlocked populations spawn in reservoir tributaries.

Biology. Semi-anadromous and landlocked populations. Spawns for the first time at 2–4 years, females 1 year later than males. Anadromous populations start entering rivers in autumn (September in Kuban) and move upstream during winter and/or in spring. Spawns in May – July, in shallows and at 18–26°C. Males assemble at spawning grounds and wait for ripe females, which arrive later. Eggs are sticky and adhere on pebbles or stones. Adults return to sea soon after spawning to forage. Young juveniles move downriver in autumn of same year or next spring. Larvae and young juveniles feed on zooplankton, algae and insect larvae, adults mainly on planktonic crustaceans, terrestrial insects, and small fish. Regularly hybridises with *Squalius cephalus*.

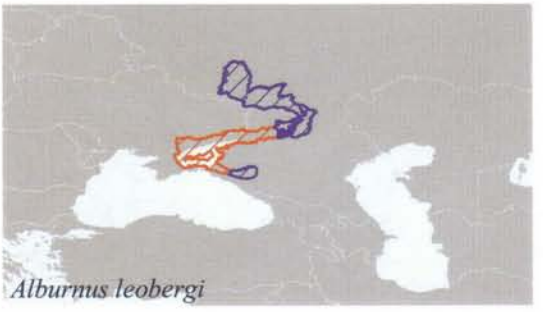
Conservation status. LC. Abundant in Azov Sea, from where it enters Don, Kuban and some small streams. During early and middle 20th century, population sharply declined as they were no longer able to reach spawning sites because of dams. Remaining populations spawn below dams.

Further reading. Berg, 1949: 738 (description; as *Chalcalburnus chalcoides schischkovi*); Freyhof & Kottelat, 2007a (description).

Alburnus macedonicus

Common name. Doiran bleak.

Diagnosis. Distinguished from other species of *Alburnus* in Balkan Peninsula by: ● slender body, depth 17–22 % SL / ○ depth of caudal peduncle 7–9 % SL, 2.2–2.8 times in its length / ○ anal origin below branched dorsal ray 4–5 / ○ 45–55 +2–3 lateral line scales / ○ 14–16½ branched anal rays / ○ 20–26 gill rakers / ○ ventral keel exposed



Alburnus leobergi

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Alburnus mandrensis; Lake Mandras, Bulgaria; ~120 mm SL.

Alburnus mento; Lake Chiemsee, Germany; ~180 mm SL. A. Hartl

for at least ²/₃ of distance from anus to pelvic base. Size up to 145 mm SL.

Distribution. Lake Doiran (Greece, Macedonia).

Habitat. Lacustrine, near shores.

Biology. Along southern shore, spawns in surf zone of lake.

Conservation status. CR A3c; B1ab(i,ii,iii) + 2ab (i,ii,iii). The water of Lake Doiran is pumped for irrigation and the lake's water level has lowered by at least 4 m since 1990; this has resulted in the disappearance of subaquatic vegetation, leading to a severe ecological stress for the entire lake. There is a risk that the lake will run dry if pumping continues at present rate.

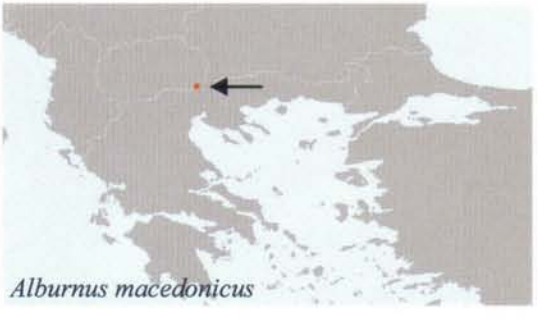
Further reading. Dimovski & Grupče, 1971 (morphology).

Alburnus mandrensis

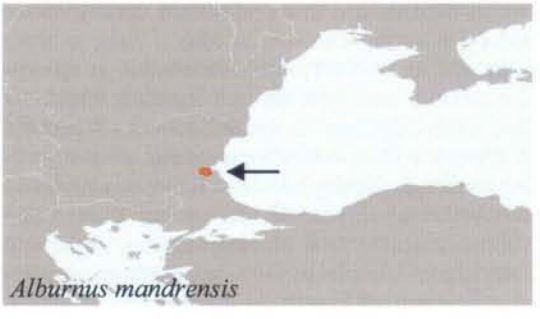
Common name. Mandras shemaya.

Diagnosis. Distinguished from other species of *Alburnus* in Aegean and Black Sea basins by: O anal origin below or about ½–1 scale behind base of last dorsal ray / O 54–63 + 4 lateral line scales / O 13–15½ branched anal rays / O base of paired fins orange in spawning adults / O 25–30 (mode 27) gill rakers / O length of gill raker at angle of upper and lower limbs of first gill arch 45–55 % of opposite inner gill filament / O ventral keel exposed for 6–8 scales in front of anus / O depth of caudal peduncle 10–11 % SL / O numerous small tubercles in nuptial males. Size up to about 180 mm SL.

Distribution. Bulgaria: Lake Mandras drainage (Black Sea basin).



Alburnus macedonicus



Alburnus mandrensis

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Alburnus mentoides; Alma, Crimea, Ukraine; ~100 mm SL.

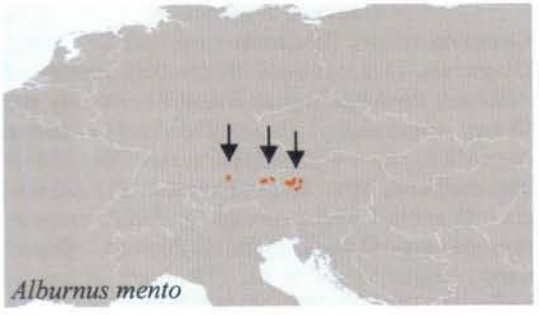
Habitat. Lacustrine. Migrates up to upper reaches of lake tributaries to spawn. Spawns in riffles with strong current, on gravel bottom.
Biology. Spawns in May – June. Forages in pelagic area of lake, close to surface. Feeds on terrestrial insects and zooplankton.
Conservation status. CR B1ab(ii,iii). Restricted range, pollution of Lake Mandras and impoundment of spawning streams.
Further reading. Drensky 1943: 7 (description).

Alburnus mento

Common name. Seelaube.
Diagnosis. Distinguished from other species of *Alburnus* in Black Sea basins by: O anal origin about 1½–2½ scales behind last dorsal ray / O 52–65 + 4 lateral line scales / O 15–17½ branched anal rays / O 21–25 gill rakers / O ventral keel exposed for 8–12 scales in front of anus (up to almost 90 % of distance between anus and pelvic base) / O depth of caudal peduncle 1.8–2.4 times in its length / O numerous small tubercles in nuptial males. Size up to 400 mm SL.
Distribution. Subalpine lakes in Danube drainage in Germany and Austria.
Habitat. Lacustrine. Migrates for short distances to lower reaches of tributary streams. Spawns in streams with strong current, on gravel bottom, rarely along lake shores.
Biology. Spawns for the first time at 4–5 years, females 1 year later than males. Spawns in May – July, in shallows, current about 1 m/s, and 12–18°C, often with much splashing. Eggs are sticky and adhere on pebbles or stones. Adults return to lakes soon after spawning to forage. Lavae move downriver soon after hatching. All age groups feed on zooplankton.
Conservation status. LC.
Further reading. Steinmann & Bless, 2004 (biology).

Alburnus mentoides

Common name. Crimea shemaya.
Diagnosis. Distinguished from other species of *Alburnus* in Black Sea basin by: O anal origin about ½–1½ scales behind last branched dorsal ray / O 58–69 + 4 lateral line scales / O 13–14½ branched anal rays / O 18–25 gill rakers / O ventral keel exposed for 8–10 scales in front of anus / O depth of caudal peduncle 1.7–1.9 times in its length / O few, large tubercles in nuptial males / O faint, dark midlateral stripe on body. Size up to about 130 mm SL.
Distribution. Streams on Crimea (Black and Azov Sea basins).
Habitat. Lower and middle parts of streams and estuaries. In estuaries, lives close to surface. Migrates to upper reaches of streams in piedmont and montane zones. Spawns in riffles with heavy current on gravel bottom.



Alburnus mento

Alburnus mentoides

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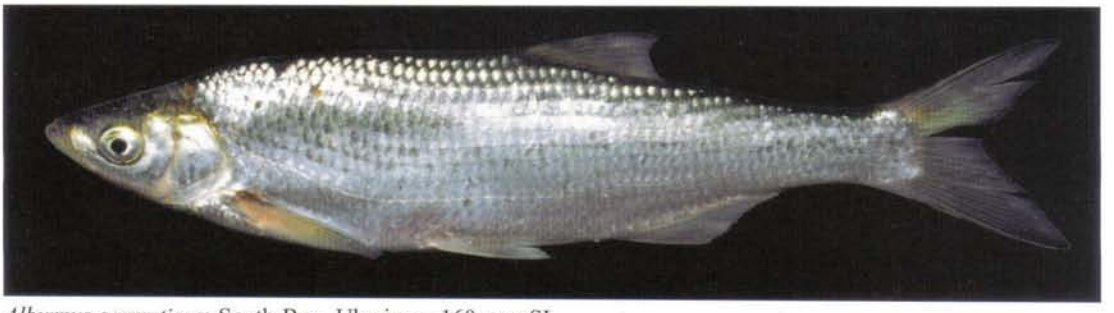


Alburnus sarmaticus; South Bug, Ukraine; ~160 mm SL.

Biology. Lives up to 5 years. Spawns for the first time at 3 years. Spawns in June – July. Forages in small stream estuaries and migrates upstream to spawn. Some juveniles forage in lower part of streams. Feeds on drifting and terrestrial insects and zooplankton. Regularly hybridises with *Squalius cephalus*.

Conservation status. EN B1ab(ii,iii,v) + 2ab(ii,iii,v), due to pollution (Salgir), water abstraction (Alma, Chornaya, Kacha) and river regulation (Chornaya). Survival in Salgir not confirmed, still abundant in stream Bel Bek. Rare in streams Kacha and Chornaya; almost extirpated in Alma.

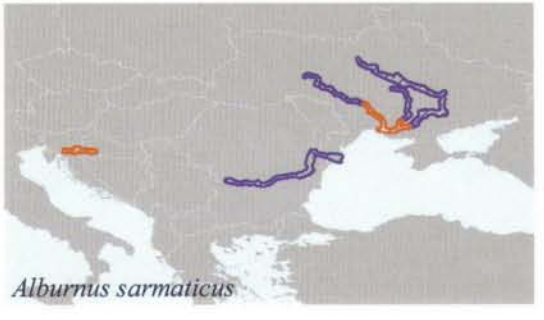
Further reading. Movchan & Smirnov, 1983: 7 (biology; as *Chalcalburnus chalcoides mento*, in part); Berg, 1949: 740 (description).

Alburnus sarmaticus

Common name. Pontian shemaya.

Diagnosis. Distinguished from other species of *Alburnus* in Black Sea basin by: ○ anal origin about 1½–2½ scales behind base of last dorsal ray / ○ 56–63 + 4–5 lateral line scales / ○ 15–17½ branched anal rays / ○ 27–34 gill rakers / ○ length of gill raker at angle between upper and lower limbs of first gill arch 30–55 % of opposite inner gill filament / ○ ventral keel exposed for 4–6 scales in front of anus / ○ numerous small tubercles in nuptial males. Size up to 250 mm SL.

Distribution. Black Sea basin: lower course of Danube, Dniepr and South Bug and coastal lakes. Almost extirpated in Danube; seems to survive only in River Kolpa, upper Save drainage (Croatia, Slovenia).



Alburnus sarmaticus

Habitat. Lower and middle parts of large rivers, estuaries, coastal lakes and adjacent areas of seas where salinity is lowered by large inflow of freshwater. Tolerates salinities up to 12 ‰. Spawns in riffles with heavy current on gravel bottom, today only below dams. Resident riverine population in River Kolpa.

Biology. Semi-anadromous and riverine populations. Spawns for the first time at 2–4 years, females 1 year later than males. Anadromous populations start entering rivers in autumn and move upstream during winter and/or spring. Spawns in May – July at 18–26°C. Eggs are sticky and adhere on pebbles or stones. Adults return to sea soon after spawning to forage. Young juveniles move downriver in autumn of same year or the following spring. Larvae and young juveniles feed on zooplankton, algae and insect larvae, adults mainly on planktonic crustaceans, terrestrial insects, and small fish. Regularly hybridises with *Squalius cephalus*.

Conservation status. EN B2ab(v). Restricted to two populations, one at the estuary of the Bug and Dniepr and one at the estuary of the Danube, possibly a single one if extirpated from Danube, with a single spawning site in each Bug and Dniepr drainages. During early and middle 20th century, all populations sharply declined as they were no longer able to reach spawning sites because of dams.

Further reading. Freyhof & Kottelat, 2007a (description).

Alburnus schischkovi

Common name. Resowska shemaja

Diagnosis. Distinguished from other species of *Alburnus* in Aegean and Black Sea basins by: ○ anal origin about 1½–2½ scales behind dorsal base / ○ 63–67 + 4 lateral line scales / ○ 13–15½ branched anal rays / ○ 21–27 (mode 25) gill rakers / ○ ventral keel exposed for 8–12 scales in front of anus / ○ head length 22–26 % SL / ○ predorsal length 55–58 % SL / ○ length of caudal peduncle 18-21 % SL, depth 2.0–2.5 times in

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The Azov Sea is one of the most important habitats for semi-anadromous cyprinids in Europe.

Semi-anadromous cyprinids

In contrast to true anadromous species, **semi-anadromous** fishes only enter brackish waters and not waters with marine salinities (more than 30 ‰). Many anadromous species inhabit a wide range of salinities but semi-anadromous species are restricted to fresh and brackish waters. In the Caspian Sea, the northern and easternmost parts of the Baltic Sea, the northern Black Sea and especially the Sea of Azov, rivers form large brackish estuaries; next to these estuaries, the seawater is diluted by freshwater discharged by the river; this area is termed the 'plume' of a river, and contains 'plume waters'.

Plumes are nutrient rich areas because of the sediments and organic material carried by the rivers, and they are the main foraging grounds of many anadromous Clupeidae, Acipenseridae and also of typical freshwater fishes (primary division families) such as *Esox*, some Cyprinidae and Percidae. Cyprinidae rarely enter brackish waters with salinities over 14 ‰. Some species (*Alburnus* spp., *Rutilus frisii*, *R. heckeli*, *R. caspicus*), populations (of *Abramis brama*, *Ballerus sapa*, *B. ballerus*, *Cyprinus carpio*, *Pelecus cultratus*, *Vimba vimba*) or individuals (of *Aspius aspius*, *Leuciscus idus*) have a semi-anadromous life history, foraging in low salinity marine areas and migrating to rivers to spawn. Semi-anadromous cyprinids usually move into rivers in autumn because overwintering in freshwater is less energy-consuming for freshwater fishes. In some species, such stocks are known as 'winter-races'. Often, individuals foraging in brackish waters grow faster, mature at larger size, spawn earlier in spring and further upstream than non-anadromous migratory or sedentary stocks, which start their spawning migration in spring ('spring races').

These differences in life history are thought to predispose to speciation because of temporal and geographic reproductive isolation of the winter and spring races. This is hypothesised to have been the mechanism of speciation that separated *Rutilus heckeli* and *R. caspicus* from *R. rutilus*. The variation in life history modes has been described in some details for many species, but unfortunately not in a way that facilitates factual and critical evaluation of its role in speciation.

Because of impoundment of all large European tributaries of the Black Sea (except for the Danube), semi-anadromous populations or species (and with them a unique opportunity to study evolution) have been almost entirely lost. Most semi-anadromous cyprinids may form landlocked and lacustrine populations inhabiting lakes or reservoirs and spawning in their tributaries.

Further reading. Berg, 1949.

length / **O** few, large tubercles in nuptial males. Size up to 210 mm SL.

Distribution. Black Sea basin: Resowska (Turkey) and Veleka (Bulgaria) drainages.

Habitat. Riverine. Migrates to upper reaches of tributaries to spawn. Spawns in riffles with heavy current on gravel bottom.

Biology. Forages in lower part of rivers, close to surface.

Conservation status. EN B1ab(ii,iii,v) + 2ab(ii,iii,v).

Remarks. Shemayas of Bulgarian rivers north to Kamtchya might also belong to this species.

Further reading. Drensky, 1943: 359 (description).

Alburnus scoranza

Common name. Scoranza.

Diagnosis. Distinguished from other species of *Alburnus* in Adriatic basin by: **O** anal origin be-

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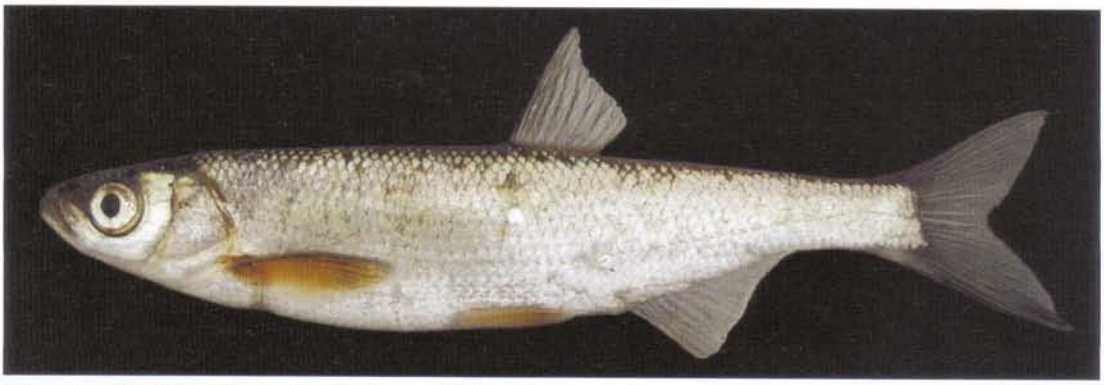

Alburnus schischkovi; Resowska, Turkey; ~140 mm SL. M. Özuluğ

Alburnus scoranza; Moraca, Drin drainage, Montenegro; ~100 mm SL.

low or immediately behind base of last branched dorsal ray / ○ 47–53 + 2 lateral line scales / ○ 13–14½ branched anal rays / ○ 17–22 gill rakers / ○ ventral keel exposed for at least ⅔ of distance from anus to pelvic base / ○ pectoral not reaching pelvic base / ○ no faint dark lateral stripe in life. Size up to 158 mm SL.

Distribution. Lakes Skadar and Ohrid basins (Montenegro, Albania, Macedonia).

Habitat. Lacustrine and in lake tributaries. Spawns on lakes shores, or migrates to tributaries to spawn in shallow riffle habitats.

Biology. Gregarious, forms large schools. Lives up to 5 years. Spawns for the first time at 1 year. In Lake Skadar, spawns in March – July, peaking in May at 18–23°C; in Lake Ohrid in May – June. Eggs are deposited on sand, gravel and rock bottom, at about 0.3 m depth. Eggs hatch in about 4 days. Feeds mainly on Cladocera and copepods.

Conservation status. LC. Very abundant, but limited area of occupancy.

Further reading. Heckel & Kner, 1858: 138 (description); Ivanovic, 1973: 100 (biology); Dimovski & Grupče, 1972 (morphology; as *A. alburnus alborella*).

Alburnus thessalicus

Common name. Thessaly bleak.

Diagnosis. Distinguished from other species of *Alburnus* in Balkan Peninsula by: ○ anal origin below branched dorsal ray 4–7 / ○ ventral keel exposed for 8–12 scales in front of anus / ○ 42–49 + 2–3 lateral line scales / ○ 14–17½ branched anal rays / ○ 18–25 gill rakers / ○ body depth 21–25 % SL / ○ depth of caudal peduncle 1.7–2.1 times in its length / ○ no or only faint dark lateral stripe (more distinct in preserved individuals). Size up to 120 mm SL.

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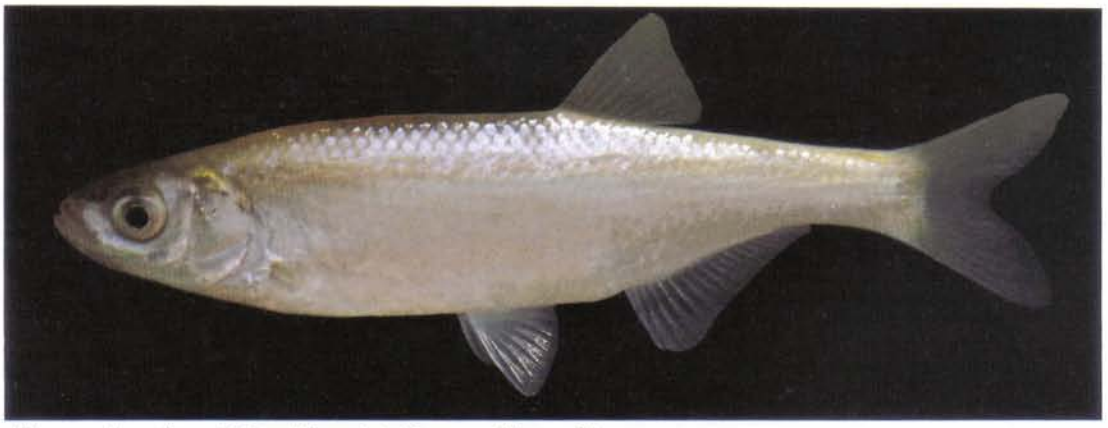
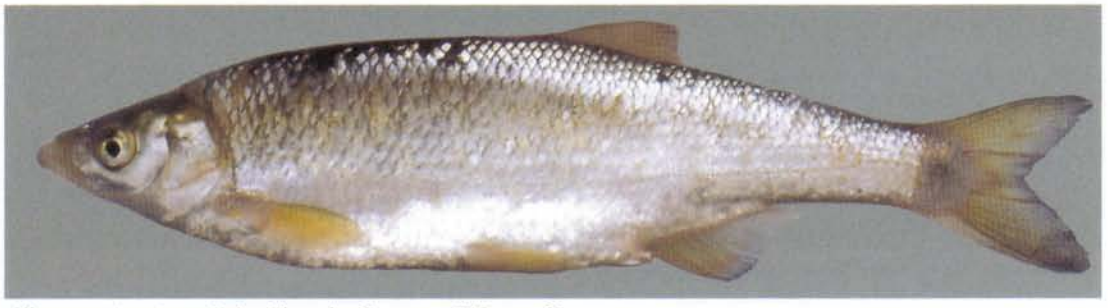


Alburnus thessalicus; Pinios (Thessaly), Greece; ~90 mm SL.



Alburnus vistonicus; Lake Vistonis, Greece; ~200 mm SL.

Distribution. From Pinios to Struma drainages (Greece, Macedonia, Bulgaria). Missing in Greek stretch of Struma and Doiran Lake.
Habitat. Open waters of medium to large rivers. Forages close to surface.
Biology. No data.
Conservation status. LC.
Further reading. Dimovski & Grupče, 1971 (description); Stephanidis, 1950: 205 (description).

Alburnus vistonicus

Common name. Vistonis shemaja.
Diagnosis. Distinguished from other species of *Alburnus* in Aegean and Black Sea basins by: O anal origin about ½–1 scales behind dorsal base / O depth of caudal peduncle 1.9–2.4 times in its length / O 57–67 + 4 lateral line scales / O 13–15½ branched anal / O 21–25 gill rakers / O ventral keel exposed for 8–12 scales in front of anus / O few, large tubercles in nuptial males. Size up to 210 mm SL.
Distribution. Lake Vistonis drainage (Greece). Shemajas from Filiouris drainage might be conspecific.
Habitat. Lacustrine. Migrates to upper reaches of tributaries to spawn in riffles with heavy current on gravel bottom.
Biology. No data.
Conservation status. CR B2ab(ii,iii).
Further reading. Freyhof & Kottelat, 2007b (description).

Alburnus thessalicus

Alburnus vistonicus

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Alburnus volviticus; Lake Volvi, Greece; ~100 mm SL.

Alburnus sp. Volvi; Lake Volvi, Greece; ~80 mm SL.

Alburnus volviticus

Common name. Yalartza.

Diagnosis. Distinguished from other species of *Alburnus* in Aegean and Black Sea basins by: ○ anal origin 1½–2½ scales behind base of last dorsal ray / ○ 56–66 + 4 lateral line scales / ○ 14–16½ branched anal rays / ○ 25–31 gill rakers / ○ length of gill raker at angle of upper and lower limbs of first gill arch 60–90 % of opposite inner gill filament / ○ ventral keel exposed for 5–8 scales in front of anus / ○ no faint, dark lateral stripe / ○ numerous small tubercles in nuptial males. Size up to about 300 mm SL.

Distribution. Greece: basins of Lakes Volvi (69 km^2, maximum depth 23 m) and Koronia.

Habitat. Lacustrine.

Biology. No data.

Conservation status. EN B1ab(i,ii,iii,iv,v) + 2ab(i,ii,iii,iv,v). Extirpated in Lake Koronia.

Further reading. Stephanidis, 1971: 142 (description, as *Chalcalburnus chalcoides macedonicus*); Economidis & Sinis, 1988 (reproduction, Lake Volvi; as *C. c. macedonicus*); Freyhof & Kottelat, 2007b (nomenclature).

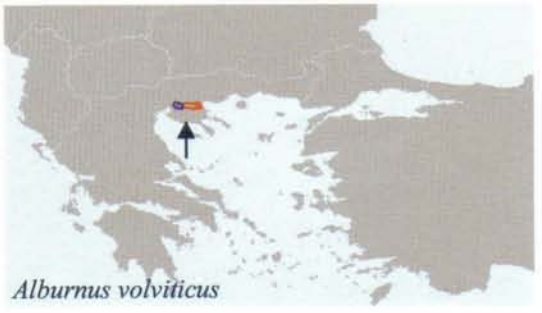
Alburnus sp. Volvi

Common name. Volvi bleak.

Diagnosis. Distinguished from other species of *Alburnus* in Balkan Peninsula by: ○ anal origin below branched dorsal rays 4–6 / ○ 44–55 + 2–3 lateral line scales / ○ 15–16½ branched anal rays / ○ 24–32 gill rakers / ○ ventral keel exposed for 8–12 scales in front of anus / ○ depth of caudal peduncle 1.8–2.3 times in its length. Size up to 110 mm SL.

Distribution. Lower Struma drainage and Lakes Volvi and Koronia (Greece).

Habitat. Open waters of medium to large rivers.



Alburnus volviticus

Alburnus sp. Volvi

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Anaecypris hispanica; Guadiana drainage, Portugal; ~45 mm SL

Forages close to surface.
Biology. No data.
Conservation status. NT. Extirpated in Lake Koronia.
Further reading. Freyhof & Kottelat, 2007b (diagnosis).

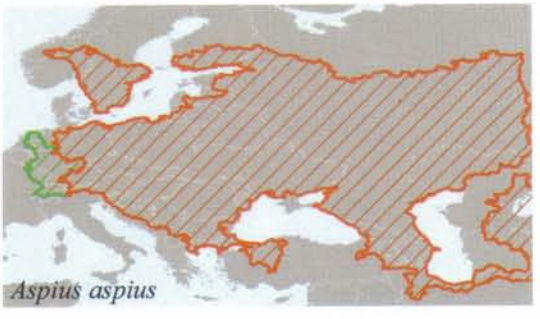
Anaecypris hispanica

Common names. Jarabugo (Spain), saramugo (Portugal).
Diagnosis. Only species of genus. Distinguished from other species of Cyprinidae in Iberian Peninsula by: ● upturned mouth / ○ dorsal origin behind pelvic base / ○ scaleless keel between pelvic and anus / ○ 58–73 total scales in midlateral row / ● lateral line incomplete, perforating 2–23 scales, sometimes absent / ● 84–130 gill rakers. Size up to 60 mm SL.
Distribution. Guadiana drainage (Spain, Portugal).
Habitat. Small streams with swift current (often pools in summer) and pebble to rock bottom, usually without submerged vegetation.
Biology. Lives up to 3 years. Spawns for the first time at 1 year, about 35 mm SL. Spawns in April – May. Fractional spawner. Moves upstream to spawn, then returns to downstream areas at beginning of summer, where permanent water is retained throughout year. Feeds on filamentous algae and small invertebrates.
Conservation status. EN A2ace. Once abundant and widespread, now rare and in fragmented populations. A conservation project started under the EU Life-Nature program.
Further reading. Bogutskaya & Collares-Pereira, 1997 (morphology); Ribeiro et al., 2000 (biology); Collares-Pereira & Cowx, 2001 (biology); Collares-Pereira et al., 2002 (biology, conservation).

Aspius aspius

Common name. Asp.
Diagnosis. Only species of genus in Europe. Distinguished from other species of Cyprinidae in Europe by: ● maxilla reaching beyond front margin of eye / ○ sharp keel between pelvic and anal origins covered by scales / ○ 64–76 total lateral line scales / ○ 12–14½ branched anal rays. Size up to 800 mm SL.
Distribution. Large rivers draining to North Sea (Weser, Elbe), Baltic Sea (southern tributaries, Norway east of Oslo, southern Sweden, Kokemären drainage in southern Finland), Black Sea, Sea of Azov and Caspian Sea; Aegean Sea basin, from Maritza to Lake Volvi drainages. Ab-

Anaecypris hispanica



Aspius aspius

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Aspius aspius; Rhine drainage, Germany; ~80 mm SL.

Aspius aspius; Danube drainage, Germany; ~650 mm SL. A. Hartl

sent in Black Sea basin south of Danube and Rioni (Georgia) drainages, but present in Turkey west of Ankara. Introduced in Rhine, Northern Dvina and Lake Balkhash (Asia). Identity of populations of Aral Sea remains uncertain.

Habitat. Open water of large and mid-sized lowland rivers and large lakes. Spawns on gravel or submerged vegetation in fast-flowing water. Lake populations migrate to tributaries.

Biology. Lives more than 10 years. Spawns for the first time at 3–5 years. Reproductive success seems to be associated with low water level and high spring temperatures. Spawns more than one season, in March – early April (mid-May in Volga), when temperatures rise above 8°C (Rhine) or even less (4–6°C in Terek), at places with strong current. Spawning lasts about 2 weeks. Eggs adhere to gravel or submerged plants. Semi-anadromous individuals or populations (Terek) forage predominantly in estuaries and freshened parts of the sea, migrating to rivers only for spawning. Starts spawning migration in second half of October (Terek) and overwinters in lower part of river. Juveniles are gregarious predators; adults hunt in small groups or are solitary. Juveniles and adults feed predominantly on fish, especially on *Alburnus alburnus* or *Osmerus eperlanus*. Juveniles grow rapidly, reaching about 80–100 mm SL during first year. Regularly hybridises with *L. idus*.

Conservation status. LC. Locally threatened by alteration of river morphology.

Remark. Molecular and morphological data suggest that *Aspius* might have to be included in *Leuciscus*.

Further reading. Barus & Oliva, 1995b: 71 (biology); Riehl et al., 2002 (reproduction).

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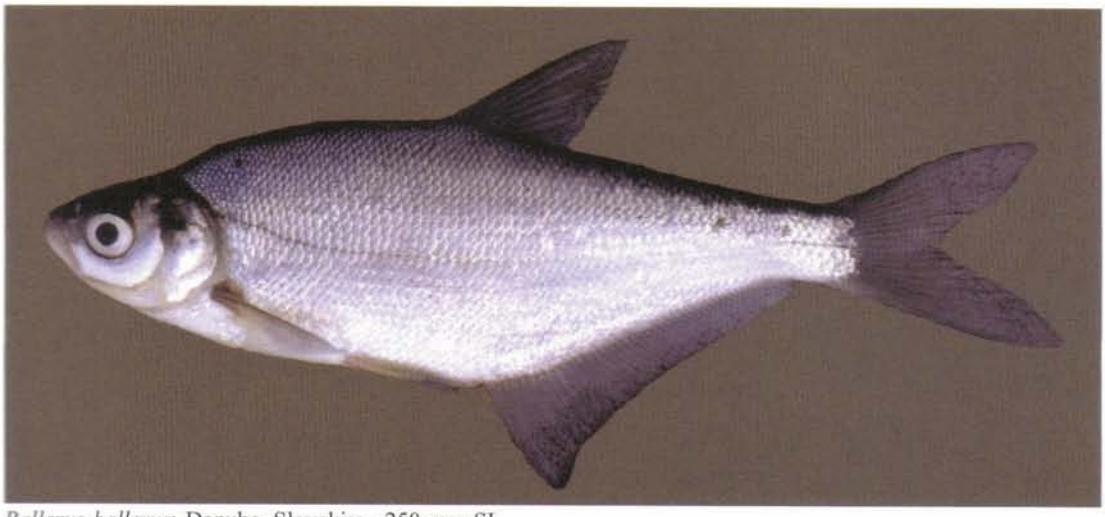

Ballerus ballerus; Danube, Slovakia; ~250 mm SL.

Ballerus

Ballerus comprises two deep-bodied species with a very long anal fin. Both were traditionally included in *Abramis* but molecular and morphological data show that they represent a distinct genus. However, molecular data suggest that *Abramis*, *Ballerus*, *Blicca*, *Vimba* and the West Asian genera *Acanthalburnus* and *Acanthobrama* are closely related.

Further reading. Bogutskaya & Naseka 2004 (generic position).

Ballerus ballerus

Common name. Blue bream.

Diagnosis. Distinguished from *B. sapa* by: ● mouth superior / ● 62–77 total lateral line scales / ● eye small, diameter about ⅔ of snout length in individuals larger than 100 mm SL. Size up to 400 mm SL.

Distribution. Large rivers draining to Baltic Sea (absent in northern Sweden and Finland north of 62°N), North Sea (Weser, Elbe), Black Sea, Sea of Azov (Don) and Caspian Sea (abundant in Volga, rare in Ural).

Habitat. Large lowland rivers with backwaters; also in eutrophic lowland lakes. Spawns on submerged vegetation along shores of rivers or in backwaters. Also reported to spawn on gravel in moderate current.

Biology. Lives more than 10 years. Spawns for the first time at 3–4 years and about 150 mm SL. Most individuals spawn several times during their life. Spawns in spring (March – April in lower Danube, April – early May in Baltic, May – June in Volga delta), when temperature reaches 10°C (8–12°C in lower Danube). Spawning period short, usually 1–2 weeks. Females spawn once a year. Males often defend spawning territories along shoreline. In mature males, sides of body above anal with nuptial tubercles. May undertake long migrations upriver to suitable spawning sites. Juveniles in backwaters and flooded zones along rivers. Enters freshened parts of seas to forage. Feeds predominantly on zooplankton in open water of backwaters and other still water bodies.

Conservation status. LC. Locally threatened due to habitat alterations along river banks.

Further reading. Berg, 1949: 763 (biology); Bănărescu, 1964: 400 (biology).

Ballerus sapa

Common name. Zobel.

Diagnosis. Distinguished from *B. ballerus* by: ● mouth small, inferior / ● 47–54 total lateral line scales / ● eye large, about equal to snout length. Size up to 250 mm SL.

Distribution. Large rivers draining to Black, Azov, Caspian and Aral Seas. Introduced or native to Northern Dvina drainage (White Sea basin) where it is presently spreading from warmer upper reaches (Vychegda system) northward. Introduced in River Volkhov (a Lake Ladoga tributary), in Rhine in 1995 and invasive in Vistula drainage, coming from Black Sea basin through Prypet-Bug canal (connecting Dniepr and Vistula drainages).

Habitat. Large lowland rivers and estuaries. Spawns in fast-flowing water on gravel bottom or submerged vegetation.

Biology. Thought to be a rheophilic, nocturnal species. Spawns for the first time at 3–4 years. Spawns in April – May when temperature rises above 8°C. Spawns in large aggregations. Semi-

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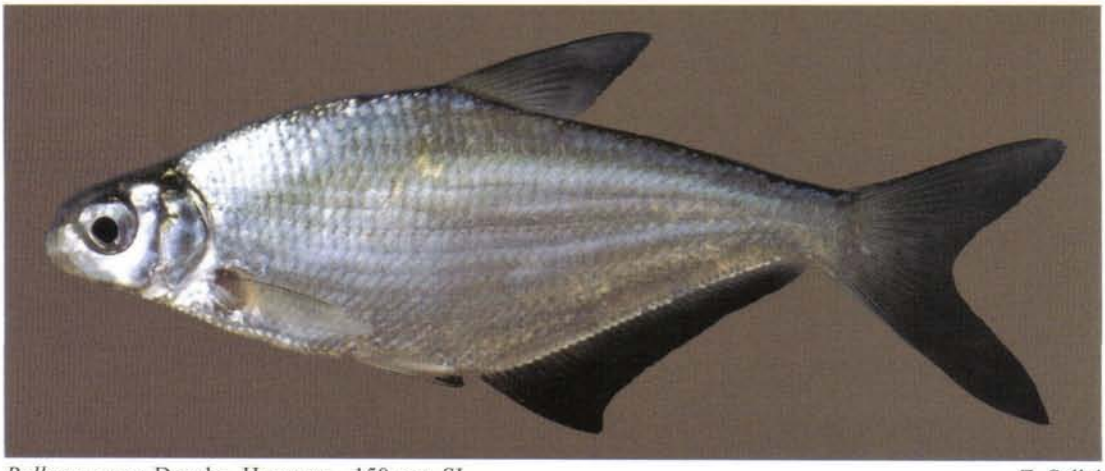

Ballerus sapa; Danube, Hungary; ~150 mm SL. Z. Sallai

anadromous populations forage in large brackish-water habitats in estuaries around Black Sea. Spawning migration of semi-anadromous individuals start in November (Kura). Feeds on benthic invertebrates.

Conservation status. LC. Usually rare and threatened by water pollution. In upper Danube, proliferates in reservoirs.

Further reading. Berg, 1949: 781 (biology); Bănărescu, 1964: 398 (biology).

Blicca bjoerkna

Common name. Silver bream.

Diagnosis. Only species of genus. Distinguished from similar species of genera *Ballerus*, *Blicca* and *Vimba* by: ○ sub-inferior mouth, which can not be extended as a tube / ○ 43–46 + 2–3 lateral line scales / ○ 19–23½ branched anal rays / ○ eye diameter about equal to snout length in individuals larger than 100 mm SL / ● pharyngeal teeth 2,5–2,5 / ○ orange or reddish base of paired fins. Size up to 330 mm SL.

Distribution. North, Baltic, White, Black (south to Rioni drainage) and Caspian Sea basins, Atlantic basin southward to Adour drainage (France; possibly introduced southward of Loire) and Mediterranean basin in France (Hérault and Rhône drainages). In Aral, Marmara and Anatolian Black Sea basins west of Ankara. Naturally absent from Iberian Peninsula, Italy, Adriatic basin, Crimea, Great Britain (except southeast), Scandinavia north of Sundsvall (Sweden) and 65°N (Finland). Locally introduced in Spain and northeastern Italy. In France apparently introduced in small coastal drainages of Var.

Habitat. A wide variety of shallow, warm lowland lakes and slow-flowing lower reaches of large rivers and canals. Often very abundant on bottom of large sandy rivers. Spawns along shores on submerged vegetation, roots or even on shallow gravel bottom.

Biology. Predominantly nocturnal. Gregarious. Lives more than 10 years. Males reproduce for the first time at 2 years, females at 3. Most individuals spawn 2–3 times per season, at intervals of about 10 days and spawn in more than one year. Spawns in May – July at temperatures above 15°C, early morning. Eggs are sticky and larvae inhabit still water bodies. Feeds on benthic invertebrates. Often hybridises with *Vimba vimba*. Most reported hybrids with *Abramis brama* in fact are *A. brama* with pharyngeal teeth 2,5–5,2 (vs. usually 5–5).

Conservation status. LC.

Further reading. Berg, 1949: 763 (biology); Bogutskaya & Naseka 2004 (generic position); Brylińska et al., 2004 (biology).

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Blicca bjoerkna; upper Danube, Germany; ~120 mm SL. A. Hartl

Blicca bjoerkna; Rhine drainage, Germany; ~180 mm SL.

Backwaters of lower Odra, Germany; habitat of *Rhodeus amarus*, *Carassius carassius* and *Misgurnus fossilis*.

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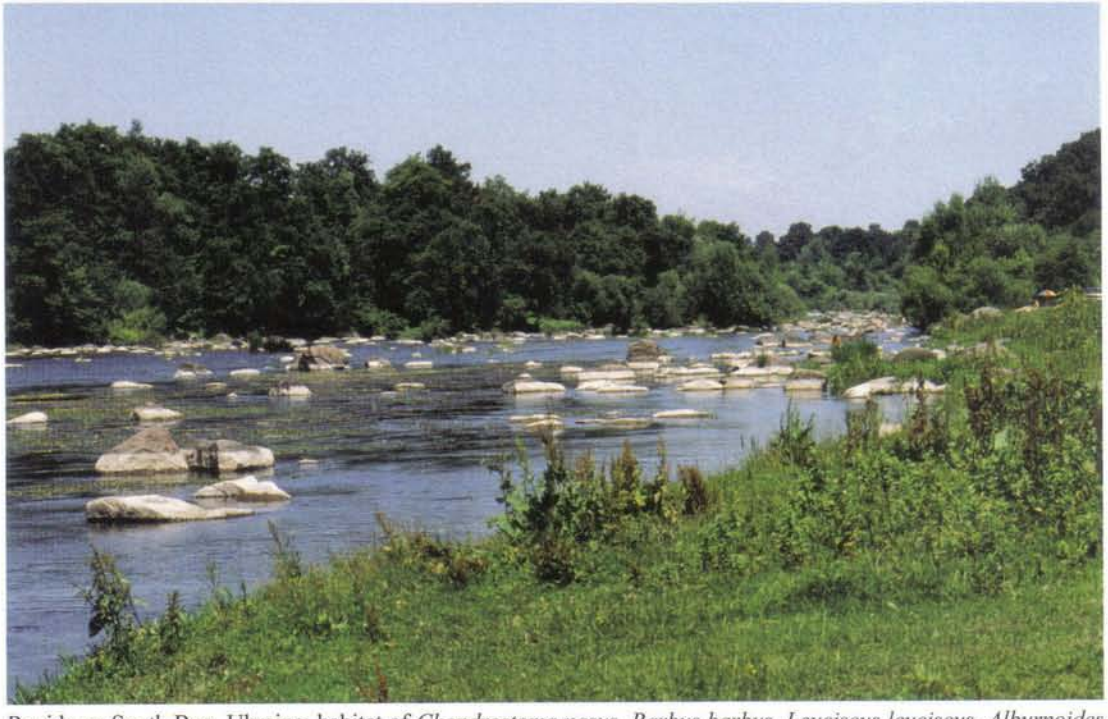
Chondrostoma nasus; Danube drainage, Germany. A. Hartl



Rapids on South Bug, Ukraine; habitat of *Chondrostoma nasus*, *Barbus barbus*, *Leuciscus leuciscus*, *Alburnoides bipunctatus* and other rheophilic species.

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Chondrostoma

For a long time, the name *Chondrostoma* was applied to an heterogeneous assemblage of species, which had in common the presence of a well developed rostral cap covering most of upper lip (Fig. 39) and a more or less developed cornified sheath covering the lower lip. They present a variety of body and mouth shapes, expected to represent distinct lineages. This diversity is especially obvious among Iberian species. Recent molecular analyses support this hypothesis and 6 genera are recognised (*Chondrostoma*, *Protochondrostoma*, *Pseudochondrostoma*, *Parachondrostoma*, *Achondrostoma*, *Iberochondrostoma*). Most of these genera are clearly defined by molecular traits but the morphological aspects have been addressed in a way that does not allow explicit diagnoses of all genera. The above key to genera (based on the published data) is unsatisfactory and the geographic origin remains an important criteria to identify some species.

Most *Chondrostoma*, *Protochondrostoma*, *Pseudochondrostoma* and *Parachondrostoma* are slender fishes inhabiting fast waters, near or on the stone bottom, where they obtain their food by scraping the algae growing on stones and rocks and the invertebrates living among them ('aufwuchs'). The adults have an inferior mouth with a cornified sheath covering the lower lip, often with a sharp edge. In some species the mouth is arched (Fig. 34a) as in most cyprinids. In more specialised species, the anterior edge of the lower lip (bearing the cornified sheath) is straight (Fig. 34b). In these species, the lower lip is distinctly fleshy only at the corners of the mouth, and the cornified sheath appears as a blade. The mouth morphology changes during ontogeny and species (as *C. nasus*) with a straight mouth in adults have an arched mouth when juveniles. The published diagnoses of several species do not efficiently differentiate them and the following keys are tentative. The validity of some of the nominal species is not clear.

Further reading. Elvira, 1987 (revision); Robalo et al., 2006b (phylogeny).

Key to species of *Chondrostoma* in Europe

Black, Baltic, Caspian and North Sea basins

1a – 8½ branched dorsal rays; eye small, diameter 44–52 % of interorbital distance. 2

1b – 9–10½ branched dorsal rays; eye large, diameter 50–65 % of interorbital distance. 3

2a – Mouth strongly arched; body cylindrical, width at dorsal origin 51–69 % of depth. ..... *C. oxyrhynchum*

2b – Mouth straight; body laterally compressed, width at dorsal origin 45–54 % of depth. ..... *C. kubanicum*

Chondrostoma nasus; feeding traces in periphyton, Rhine drainage, Germany.

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3a – Usually 55–57 (range 50–62) total lateral line scales.
..... *C. variabile*
3b – Usually 60–63 (range 52–66) total lateral line scales.
..... *C. nasus*

Mediterranean basin

1a – 78–106 total lateral line scales.
..... *C. phoxinus*
1b – 50–66 total lateral line scales.
..... 2

2a – Mouth strongly arched (semi-circular).
..... 3
2b – Mouth straight or slightly arched.
..... 4

3a – 14–17 gill rakers.
..... *C. scodrense*
3b – 19–24 gill rakers.
..... *C. knerii*

4a – 11–13½ branched anal rays; no red colour in pectoral, pelvic and anal.
..... *C. soetta*
4b – 8–11½ branched anal rays; pectoral, pelvic and anal red.
..... 5

5a – 23–27 gill rakers; cornified sheath on lower lip thin.
..... *C. prespense*
5b – 27–38 gill rakers; cornified sheath on lower lip thick.
..... 6

6a – 9–10½ branched dorsal rays.
..... *C. nasus*
6b – 8½ branched dorsal rays.
..... *C. vardarense*

Chondrostoma knerii

Common name. Dalmatian nase.
Diagnosis. Distinguished from other species of *Chondrostoma* in Western Balkans and Adriatic basin by: ● 50–59 total lateral line scales / ● mouth arched and lower lip with thin cornified sheath / ● ½7–8/1/5 scales in transverse row between dorsal and pelvic origins / ● 8–9½ branched dorsal rays / ● 8–9½ branched anal rays / ● 19–24 gill rakers. Size up to about 200 mm SL.
Distribution. Neretva drainage (Croatia, Bosnia-Herzegovina).
Habitat. Streams with clear water, lakes.
Biology. Spawns in March.
Conservation status. VU D2.
Further reading. Elvira, 1987: 121 (systematics).

Chondrostoma kubanicum

Common name. Kuban nase.
Diagnosis. Only species of genus in Kuban drainage. Distinguished from other species of *Chondrostoma* in Black and Caspian Sea basins by: ● mouth straight, lower lip with thick cornified sheath / ● 54–62 total lateral line scales / ● usually 8½ branched dorsal rays / ● eye small, diameter 44–52 % of interorbital distance / ● body laterally compressed, width at dorsal origin 45–54 % of depth / ● usually 10½ branched anal rays / ● no dark lateral stripe on body. Size up to 350 mm SL.
Distribution. Black Sea basin: Kuban drainage.
Habitat. Piedmont and montane rivers with strong current and gravel bottom. Most of year in middle or upper stretches of rivers; in winter, moves downstream to lower stretches or larger tributaries.
Biology. Spawns for the first time at 3 years, females often 1 year later. In January – February,

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Chondrostoma knerii; lower Neretva, Bosnia-Herzegovina; ~100 mm SL.

Chondrostoma kubanicum; Kuban drainage, Russia; ~200 mm SL.

starts spawning migration to uppermost montane reaches, entering small shallow streams with very fast current. Spawns in March – May at sites with gravel or hard sand, with rapids and swift current (up to 1.5 m/s), 0.2–1.0 m deep, in clean water with high oxygen concentrations. Females lay 1000–1250 eggs, during a short period, usually in a single night, but often in several portions. Most individuals at a given spawning site spawn over 3–4 nights. Eggs are sticky and adhere to substrate. Feeds mainly on detritus, also on periphyton, benthic invertebrates, especially during first year of life.

Conservation status. LC. Very sensitive to water quality, especially turbidity. Possibly declined during 20th century because of construction of Krasnodar dam. Most likely stabilised since. Still rather numerous in middle and upper stretches of non-regulated Kuban tributaries.

Further reading. Elvira, 1987: 118 (taxonomy); Troitskiy & Tsunikova, 1988 (biology); Emtyl, 1997 (biology).

Chondrostoma nasus

Common name. Nase.

Diagnosis. Distinguished from species of *Chondrostoma* in Black and Caspian Sea basins by: ○ mouth straight in individuals larger than 200 mm SL, lower lip with thick cornified sheath / ○ 9½ branched dorsal rays / ○ 52–66 (usually 60–63) total lateral line scales / ○ 10–11½ branched anal rays / ○ eye large, diameter 50–65 % of interorbital distance / ○ no broad dark midlateral stripe on side.

Distinguished from species of *Chondrostoma*, *Protochondrostoma* and *Parachondrostoma* in Atlantic, Adriatic and Mediterranean basins of France, Italy and Slovenia by: ○ mouth straight,

Chondrostoma knerii

Chondrostoma kubanicum

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Chondrostoma nasus; Danube drainage, Germany; ~400 mm SL. A. Hartl

lower lip with thick cornified sheath / ○ 27–36 gill rakers / ○ 10–11½ branched anal rays / ○ pectoral, pelvic, anal and caudal red. Size up to 460 mm SL.

Distribution. Basins of Black (Danube, Dniestr, South Bug and Dniepr drainages), southern Baltic (Nieman, Odra, Vistula) and southern North Seas (westward to Meuse). Invasive or introduced in Rhône, Loire, Hérault, Seine (France) and Soca (Italy, Slovenia) drainages.

Habitat. Moderate to fast-flowing large to medium sized rivers with rock or gravel bottom. Spawns in fast-flowing water on shallow gravel beds often in small tributaries. May show a strong size related longitudinal distribution in smaller rivers, with adults inhabiting more upper river stretches.

Biology. Lives up to 12 years. Spawns for the first time at 4–5 years. May migrate some tens of km to spawning sites, which are often situated in tributaries, but which it does not inhabit in summer. Spawns in March – May when temperature reaches 12°C. Males form large aggregations, each male defending a small territory. Females spawn only once a year and, in some populations, during a very short period (3–5 days). Females deposit the sticky eggs into excavations made in gravel. Feeding larvae live along shores. Larvae live below surface. Early juveniles are benthic and inhabit very shallow shoreline habitats. When growing, they leave the shores for faster-flowing waters. Recruitment is closely related to high spring temperature, absence of spring floods and available shallow-water habitats along shores. Juveniles overwinter in backwaters or in cavities along shores. Adults form dense swarms during winter in lower parts of rivers. Larvae and early juveniles with superior mouth feed on small invertebrates. Larger juveniles and adults, which have inferior mouth, feed on benthic diatoms and detritus cleaned up from hard substrate in habitats with strong current.

Conservation status. LC. Locally threatened due

Chondrostoma nasus, spawning aggregation; Danube, Germany. A. Hartl

Chondrostoma nasus, spawning; Danube, Germany. A. Hartl

Chondrostoma nasus

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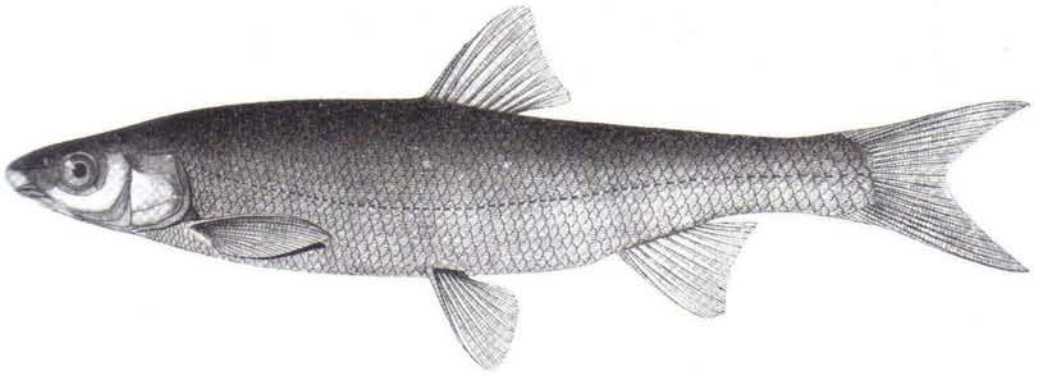

Chondrostoma oxyrhynchum; Sunzha drainage, Caspian basin, Russia, ~200 mm SL. (from Berg, 1914)

to damming, destruction of spawning sites and pollution. But in drainages where it is not native, it outcompetes and eliminates *Parachondrostoma toxostoma* (Rhône) and *Protochondrostoma genei* (Soca) where the access to their range is not prevented by weirs.

Remarks. Individuals reported as *C. nasus* from the Drin drainage (including Lakes Ohrid and Skadar) apparently represent a distinct species.

Further reading. Nelva, 1989 (biology); Maier et al., 1995 (biology).

Chondrostoma oxyrhynchum

Common name. Terek nase.

Diagnosis. Distinguished from species of *Chondrostoma* in Black and Caspian Sea basins by: ● mouth strongly arched / ○ usually 8½ branched dorsal rays / ○ 56–73 total lateral line scales / ○ 9–10½ branched anal rays / ○ eye small, diameter 48–52 % of interorbital distance / ○ body cylindrical, width at dorsal origin 51–69 % of depth. Size up to 460 mm SL.

Distribution. West Caspian basin, from Kuma to Samur drainages.

Habitat. Piedmont and mountain rivers with strong current and rock to gravel bottom. Spawns over hard bottom.

Biology. Spawns for the first time at 2 years, about 120 mm SL. Spawns in March – April. Females lay eggs probably in several portions. Eggs adhere to gravel. Feeds mainly on detritus, and also on periphytic algae and benthic invertebrates, especially during first year of life.

Conservation status. LC.

Further reading. Berg, 1949: 629 (taxonomy); Abdurakhmanov, 1962: 133 (biology); Elvira, 1987: 122 (systematics).

Chondrostoma phoxinus

Common name. Livno nase.

Diagnosis. Distinguished from other species of *Chondrostoma* in Western Balkans and Adriatic basin by: ● 78–106 total lateral line scales / ○ mouth arched, lower lip with very thin cornified sheath / ○ posterior margin of dorsal slightly concave to convex / ● ½13–21/1/8–13 scales in transverse row between dorsal and pelvic origins / ○ 8½ branched dorsal rays / ○ 8–9½ branched anal rays / ○ 23–28 gill rakers. Size up to 155 mm SL

Distribution. Bosnia-Herzegovina: Glamočko, Livansjko and Duvanjsko poljes; Croatia: Cetina drainage.

Habitat. Slow-flowing streams, lakes; enters subterranean waters.

Biology. Abundant in lacustrine conditions, able to colonize still water bodies (shallow clay pits without gravel, sand, current, waves or tributaries) and therefore spawning on submerged plants.

Chondrostoma oxyrhynchum

Chondrostoma phoxinus

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Chondrostoma phoxinus; Lake Buško, Bosnia-Herzegovina; ~90 mm SL.

Chondrostoma prespense Lake Prespa, Greece; ~200 mm SL. Society for Protection of Prespa

Conservation status. EN B1ab(i,ii,iii,iv,v), due to restricted range, water abstractions and pollution. Sharply declined during 20th century due to habitat destruction and pollution. Largest population in Lake Buško (Bosnia-Herzegovina) threatened by recently introduced *Silurus glanis*.
Further reading. Elvira, 1987: 123 (systematics).

Chondrostoma prespense

Common name. Prespa nase.
Diagnosis. Distinguished from other species of *Chondrostoma* in Balkan Peninsula by: ○ mouth slightly arched, lower lip with thin cornified sheath / ○ 56–66 total lateral line scales / ○ ½8–9/1/5–6 scales in transverse row between dorsal and pelvic origins / ○ 8½ branched dorsal rays / ○ 8–9½ branched anal rays / ○ 23–27 gill rakers. Size up to 270 mm SL.
Distribution. Lakes Prespa basin (Greece, Macedonia, Albania).
Habitat. Lacustrine, enters tributaries in spawning season.
Biology. Lives up to 5 years. Spawns for the first time at 2 years. Spawns in April – May. In Mikri Prespa, which has no tributary, spawns on gravel beds, near shore. In Megali Prespa, spawns on sandy beaches and in tributaries and returns directly to lake. Migrates exclusively at night. Feeds on macrophytes, supplemented by invertebrates.
Conservation status. VU D2.
Further reading. Elvira, 1987: 127 (systematics); Catsadorakis et al., 1996: 15 (reproduction); Crivelli et al., 1997 (biology).

Chondrostoma scodrense

Common name. Skadar nase.
Diagnosis. Distinguished from other species of *Chondrostoma* in Balkan Peninsula by: ○ mouth

Chondrostoma prespense

Chondrostoma scodrense

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Chondrostoma scodrense; Lake Skadar drainage, Montenegro; 132 mm SL P. Zupančič

Chondrostoma soetta; Lake Lugano, Switzerland; 335 mm SL.

strongly arched, with thin but well developed cornified sheath on lower lip / ○ 51–59 total lateral line scales / ○ ½8/1/4 scales in transverse row between dorsal and pelvic origins / ○ 8–9½ branched dorsal rays / ○ 9–10½ branched anal rays / ● 14–17 gill rakers. Size up to at least 135 mm SL.

Distribution. Lake Skadar basin (Montenegro, Albania).

Habitat. No data.

Biology. No data.

Conservation status. EX. Believed to be extinct, but this is probably a premature conclusion as there are no reliable field data. Known only from museum specimens collected in 1881.

Further reading. Elvira, 1987: 129 (systematics).

Chondrostoma soetta

Common name. Savetta.

Diagnosis. Distinguished from other species of *Chondrostoma* and *Protochondrostoma genei* in Apennine Peninsula by: ○ no broad dark midlateral stripe on side / ● body deep, depth 25–34 % SL / ○ mouth straight, lower lip with thick cornified sheath / ○ 54–62 total lateral line scales / ○ 11–13½ branched anal rays / ○ 24–29 gill rakers. Size up to 350 mm SL.

Distribution. Adriatic basin, from Soca to Po drainages (Slovenia, Italy). Introduced to central Italy.

Habitat. Lakes and lower reaches of main rivers with moderate current, in deep water, over gravel bottom.

Biology. Gregarious. Spawns for the first time at 3–4 years. Large groups undertake spawning migrations towards smaller tributaries in April – May. Eggs are spawned in gravel, in current, near shore. Threatened in Soca drainage by introduced *C. nasus*, but responsible for local extirpation of native species where it has been stocked in central Italy. Feeds mainly on vegetal matter, especially epilithic algae, and molluscs.

Conservation status. EN B2ab(i,ii,iii,iv,v). Declined due to habitat alterations in large lowland rivers. Extirpated in Slovenia in the 1960s.

Further reading. Elvira, 1987: 130 (diagnosis); Gandolfi et al., 1991: 183 (biology); Bianco, 1995a: 165 (distribution); Maier et al., 1995: 46 (biology).

Chondrostoma vardarense

Common name. Vardar nase.

Diagnosis. Distinguished from other species of

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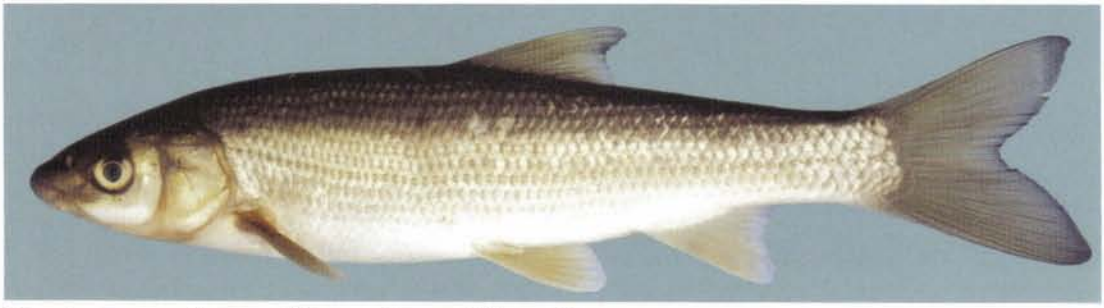


Chondrostoma vardarense; Aliakmon, Greece; 175 mm SL.

Chondrostoma variabile; Volga delta, Russia; 90 mm SL.

Chondrostoma in Balkan Peninsula by: ○ mouth straight, lower lip with thick cornified sheath / ○ 57–66 total lateral line scales / ○ ½8–9/1/5–6 scales in transverse row between dorsal and pelvic origins / ○ 8½ branched dorsal rays / ○ 9½ branched anal rays / ○ 28–38 gill rakers. Size up to about 350 mm SL.

Distribution. Aegean basin, from Maritza to Pinios drainages (Turkey, Bulgaria, Greece, Macedonia); Adriatic basin in Aoos drainage (Greece, Albania).

Habitat. From rivers to brooks, over stone to rock bottom, with fast to strong current.

Biology. Ascends tributaries to spawn in rapids and riffles among stones.

Conservation status. NT.

Further reading. Elvira, 1987: 134 (systematics).

Chondrostoma variabile

Common name. Volga nase.

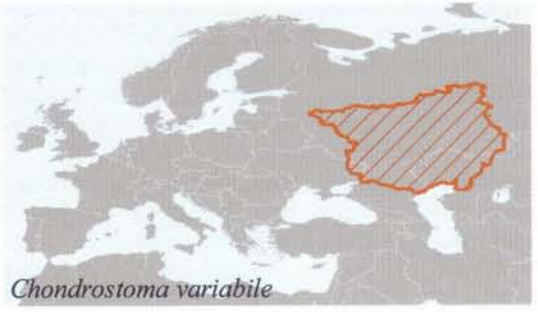
Diagnosis. Distinguished from other species of *Chondrostoma* in Black and Caspian Sea basins by: ○ mouth straight or slightly arched / ○ 9½ branched dorsal rays / ○ 50–62 total lateral line scales / ○ usually 10½ branched anal rays / ○ eye large, diameter 50–65 % of interorbital distance. Size up to 280 mm SL.

Distribution. Caspian basin, in Emba, Ural and Volga (with Oka and Kama) drainages; Black Sea basin, in Don drainage.

Habitat. Lowland and piedmont rivers with moderate to strong current; also in reservoirs. Common in river main courses in rapids, sandy shallows and river curves. Spawns on gravel or rock bottom in shallow riffles of larger rivers or in smaller tributaries with moderate to strong current.

Biology. Lives up to 7 years. Spawns for the first

Chondrostoma vardarense



Chondrostoma variabile

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time at 2–3 years, females usually 1 year later. Spawns in April – May. Eggs are sticky, adhere to gravel. Larvae and early juveniles with superior mouth feed on small invertebrates. After 3–4 months, juveniles about 30–35 mm SL change to adult feeding mode and graze benthic diatoms and detritus from hard substrate in habitats with strong current. Most of year in middle and upper stretches of rivers, moving in winter to lower stretches or to larger tributaries. Reported to occur year round in lower reaches and deltas of Volga and Ural.

Conservation status. LC. No reliable data. Sharply declined in parts of Volga drainage because of impoundment and water regulation during 20th century. Most likely stabilised at a low or moderate level since.

Further reading. Kontrimavichyus, 1984 (morphology, biology); Smirnov, 1992 (systematics).

Delminichthys

Morphological and molecular evidences show that species of *Phoxinellus* of earlier authors belong to three distinctive lineage. *Delminichthys* is one of them. Several other species are now placed in *Telestes* and others remain in *Phoxinellus*. Species of *Delminichthys* are small fishes, with very thin, non-overlapping scales, lateral line often incomplete or interrupted, and a protruding genital papilla in female. They inhabit small karstic basins and are endemic to Croatia and Bosnia-Herzegovina.

Further reading: Freyhof et al., 2006 (systematics, genetics).

Key to species of *Delminichthys*

1a – Groove behind upper lip interrupted in middle (Fig. 43); 80–100 pored scales along lateral line. ..... *D. ghetaldii*

1b – Groove behind upper lip not interrupted in middle; 4–78 pored scales along lateral line. 2

2a – Eye diameter equal to or greater than snout length; usually 54–70 pored scales along lateral line. ..... *D. adspersus*

2b – Eye diameter smaller than snout length; 20–60 pored scales along lateral line. 3

3a – Snout conical, pointed; mouth terminal; lateral line usually ending on caudal peduncle; usually 51–60 pored scales along lateral line. ..... *D. jadovensis*

3b – Snout stout, markedly rounded; mouth subterminal; lateral line interrupted several times, ending from behind pectoral to above anal base; usually 20–40 pored scales along lateral line. ..... *D. krbavensis*

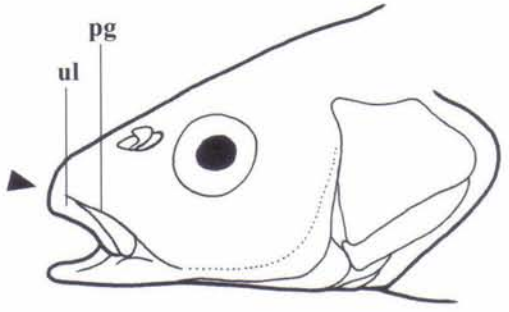

Figure 43 Groove behind upper lip medially interrupted (arrow) in *Delminichthys*. **pg,** postlabial groove; **ul,** upper lip (after Bogutskaya & Zupančič, 2003).

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Delminichthys adspersus; Matica, Croatia; ~65 mm SL.

Delminichthys adspersus

Common name. Gaovica.

Diagnosis. Distinguished from other species of *Delminichthys* by: ● eye large, diameter 26–29 % HL, equal to or larger than snout length / ○ snout conical, not stout, mouth terminal / ○ skin thickened especially in adults during spawning season; scales distinct or not, covering whole body, often narrowly to widely separated in particular in pre-pelvic area / ○ lateral line interrupted or not, usually ending on caudal peduncle / ○ usually 54–70 pored lateral line scales in adults. Size up to 90 mm SL.

Distribution. Vrljika drainage and Lake Crveno in Imotsko polje, Matica and Norin drainages, Lakes Kuti and Bačina in Neretva drainage (Croatia); Tihaljina and Trebizat system in Neretva drainage (Bosnia-Herzegovina).

Habitat. In streams, lakes and springs with clear water. Enters subterranean waters during winter or droughts.

Biology. Spawns in May – July. Females spawn for the first time at about 56 mm SL, males at about 47–55 mm SL. Males are smaller then females.

Conservation status. VU B2ab(iii); threatened by habitat destruction and pollution, which are expected to increase with economic development.

Further reading. Karaman, 1972:133 (description); Bilopavlović, 1970: 221 (biology); Bogutskaya & Zupančič, 2003 (morphology).

Delminichthys adspersus

Delminichthys ghetaldii

Common name. Popovo minnow.

Diagnosis. Distinguished from other species of *Delminichthys* by: ● lips markedly thickened laterally, groove behind upper lip interrupted in middle (Fig. 43) / ● upper jaw not protrusible / ● 80–100 pored lateral line scales in adults, 100–110 total scales in midlateral row / ○ scales deeply embedded in skin; skin conspicuously thickened in adults, especially during spawning season when most scales become indistinct; they are relatively distinct in juveniles and small adults outside spawning season / ○ scales narrowly to widely spaced, covering whole body / ● 19–26½ scales rows between lateral line and dorsal origin. Size up to 130 mm SL.

Distribution. Streams and springs in Popovo, Ljubomirsko, Dabarsko and Fatnicko poljes (Bosnia-Herzegovina); Bacina lakes and some springs in southern Dalmatia (Croatia).

Habitat. Streams with clear water. Enters subterranean waters and caves.

Biology. Spawns in May, probably also later. Females spawn for the first time at about 61 mm SL.

Conservation status. VU B1ab(ii,iii) + 2ab(ii,iii), threatened by habitat destruction and pollution, which are expected to increase with economic development.

Remarks. *Phoxinellus pstrossii* is a synonym.

Further reading. Steindachner, 1882: 16 (description); Bogutskaya & Zupančič, 2003 (morphology).

Delminichthys jadovensis

Common name. Jadova minnow.

Diagnosis. Distinguished from other species of *Delminichthys*: ○ snout conical, not stout, mouth terminal / ○ body entirely covered by scales, scales relatively small, widely spaced especially on dorsal and ventral surfaces / ○ scales deeply embedded in skin; skin conspicuously thickened in adults especially during spawning season when

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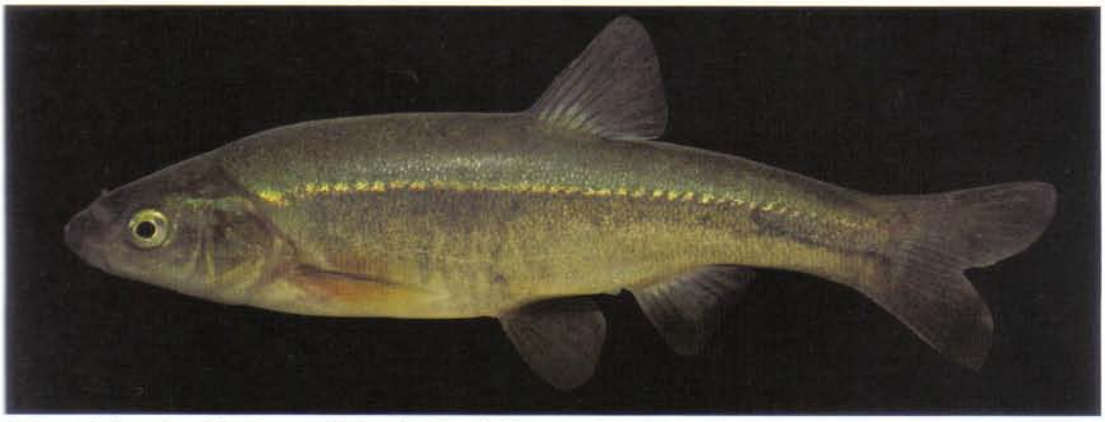

Delminichthys ghetaldii; Stream Ljubomir, Bosnia-Herzegovina; 76 mm SL.

Delminichthys jadovensis; Jadova, Croatia; ~60 mm SL.

most scales are not visible / ● lateral line scales located close to each other and larger than remaining scales of body / ○ lateral line interrupted or not, usually ending on caudal peduncle, usually with 51–60 pored scales. Size up to 93 mm SL.

Distribution. Croatia: River Lika and its tributary Jadova.

Habitat. Streams with slow current and clear water. In karstic areas, enters subterranean waters and springs. Depending on water level, may spend winter in subterranean waters or hidden in mud.

Biology. Females spawn for the first time at about 58 mm SL. Spawns in June – July. Females lay 1200–1500 eggs, probably in 2–3 portions. During spawning season, females develop small red spots on belly and red bases of pelvic and anal fins. After spawning, move into subterranean stretches of streams; when water level increases again (in autumn) may return to surface stream.

Conservation status. CR B1ab(iii,iv), threatened by increasing water abstraction and introduction of *Squalius cephalus* and *Lepomis gibbosus*.

Further reading. Trgovcevic, 1905: 12 (as *Paraphoxinus adspersus*; morphology, biology); Zupančič & Bogutskaya, 2002: 430 (description).

Delminichthys krbavensis

Common name. Krbava minnow.

Diagnosis. Distinguished from other species of *Delminichthys*: ● distance between pelvic and

Delminichthys ghetaldii

Delminichthys jadovensis

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Delminichthys krbavensis; Krbava, Croatia; ~80 mm SL.

anal origins short, 54–65 % of distance between pectoral and pelvic origins / O snout stout, markedly rounded, mouth subterminal / O all scales deeply embedded in skin; skin markedly thickened and folded in adults, especially during spawning season when most scales are not distinct / O lateral line scales more or less widely separated from each other, larger then body scales / ● body scales roundish or irregular, very small, widely separated, missing in pre-pelvic area and immediately behind head / O lateral line broadly interrupted, ending from behind pectoral to above anal base, usually 20–40 pored scales. Size up to 100 mm SL.

Distribution. Croatia: Krbavsko Polje karst.

Habitat. Streams with clear water. In karstic areas, enters subterranean waters and springs.

Biology. Spawns in May – July. Females lay 1000–1200 eggs, probably in several portions. Ripe males have small nuptial tubercles on upper surface of head and inner surface of pectoral. Pectoral and pelvic longer in males than in females.

Conservation status. CR B1ab(ii,iii,iv) + 2ab(ii, iii,iv), threatened by increasing water abstraction and introduction of *Salmo trutta* and *Oncorhynchus mykiss*.

Further reading. Trgovcevic, 1905: 14 (as *Paraphoxinus ghetaldii*; morphology, biology); Zupančič & Bogutskaya, 2002: 424 (description).

Hypophthalmichthys

Two of the three species of this genus have been introduced to Europe but, as far as known, they did not establish self-sustaining populations. *Hypophthalmichthys* were introduced from the Amur (Siberia) to European Russia and from the Yangtze (China) to Romania. From these two areas, they were transported all over Europe for aquaculture and most major rivers were stocked. The first importation of these fishes to Romania is a great example of how careless fish introductions have often been handled. In 1961, unidentified fish larvae were caught in the Yangtze close to the city of Wuhan and released in an aquaculture station close to Bucharest. When the ponds were drained in autumn, 22 Chinese fish species were recorded, including *Hypophthalmichthys* and *Pseudorasbora*. While the other introduced species could be successfully eliminated, *Peudorasbora* escaped from the ponds and is still expanding its range throughout Europe, western Asia and northern Africa. *Hypophthalmichthys* and other introduced Chinese cyprinids also hosted several parasites, which also conquered Europe, the most spectacular being the large freshwater mussel *Sinanodonta woodiana*. The position of *Hypophthalmichthys* in the subfamily Leuciscinae is still under debate; *Hypophthalmichthys nobilis* is still placed in *Aristichthys* by some authors.

Hypophthalmichthys molitrix

Common name. Silver carp.

Diagnosis. Distinguished from *H. nobilis* by: ● sharp scaleless keel from pectoral region to anal origin / ● 650–820 long, slender gill rakers / O head length 24–29 % SL / ● plain pale colora-

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Hypophthalmichthys molitrix; Volga delta, Russia; ~500 mm SL.

tion, greenish grey above, whitish below. Size up to 1000 mm SL and 50 kg.

Distribution. Native to most major Pacific drainages of East Asia from Amur to Xi Jiang. Used in aquaculture in Europe, Asia and North America; introduced in most European drainages. Established reproductive populations in North America and Central Asia.

Habitat. Stocked in large rivers and almost all still water bodies as lakes and ponds. Often escapes from fish farms. In aquaculture, tolerates brackish water (up to 7 ‰) when released into estuaries and coastal lakes. In its original range, inhabits rivers with conspicuous water-level fluctuations, overwintering in middle and lower stretches. During foraging period, in shallow (0.5–1.0 m deep) and warm (above 21°C) backwaters, lakes and flooded areas with slow current. Spawns in rivers or tributaries over shallow rapids with gravel or sand bottom, high current (0.5–1.7 m/s), turbid water, temperatures above 15°C (usually 18–26°C) and high oxygen concentrations.

Biology. Spawns for the first time at 5–7 years. Juveniles and adults form large schools during spawning and overwintering form large schools. Migrates long distances upriver at beginning of a rapid flood and water-level increase (in April – August depending on locality), able to jump over obstacles up to 1 m. Spawns during floods when the water level increases by 50–120 cm above normal level. Stops spawning if conditions change (especially sensitive to water-level fall, reduced turbidity and increased current velocity) and starts again with increase of water level. Spawns in upper water layer or even at surface. Females lay about 500,000 eggs in one or several portions depending on duration of high-water period. Eggs float, are transparent, and hatch while drifting downstream, after about 2 days at about 25°C. If river flow is blocked or if available river stretches are too short, eggs cannot drift long enough and fail to develop. After spawning, adults leave the river and migrate to foraging habitats. In autumn-winter, they migrate to deeper places in main course of river where they remain without feeding. Larvae drift downstream and settle in floodplain lakes, shallow shores and backwaters with little or no current. Feeds from about 15 mm SL only on phytoplankton. Larvae and small juveniles eat zooplankton. Very sensitive to low temperature (below 5°C) and oxygen deficit. There are reliable data on natural spawning in rivers of southern Russia and in lower Danube, but it is not known whether eggs and larvae have been able to complete development. Often crossed with *H. nobilis*.

Conservation status. Alien. In Europe survives only by stocking. Native wild stocks in Russia and China are declining.

Further reading. Holčík, 1976: 90 (introduction, Danube); Movchan & Smirnov, 1983: 305 (morphology, biology); Howes, 1981 (anatomy).

Hypophthalmichthys nobilis

Common name. Bighead carp.

Diagnosis. Distinguished from *H. molitrix* by: ● scaled keel from pelvic to anal / ● 240–300 long gill rakers / ○ head length 27–35 % SL / ● dark overall coloration, flank with dark, large, very irregularly shaped blotches, fin bases and inferior parts of head and belly yellowish. Size up to 1460 mm SL and 40 kg.

Distribution. Native to Central and South China. Used in aquaculture in Europe, Asia and North America; introduced in most European drainages. Reliable data on natural spawning in Europe. Established reproductive populations in North America and Central Asia.

Habitat. Stocked to large rivers and almost all still water bodies as lakes and ponds. Often escaped from fish farms. In aquaculture, adults tolerate brackish water (up to 7 ‰) when released into estuaries and coastal lakes. In its original range,

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Hypophthalmichthys nobilis; Shanghai, China; ~600 mm SL.

inhabits rivers with marked water-level fluctuations, overwinters in middle and lower stretches. During foraging period in shallow (0.5–1.5 m deep) and warm (more than 24°C) backwaters, lakes and flooded areas with slow current. Spawns in very deep, very turbid and warm water, above 18°C (usually 22–30°C), with high current (1.1–1.9. m/s) and high oxygen concentrations.

Biology. Lives up to 20 years. Spawns for the first time at 5–6 years, 550-700 mm SL and 5-10 kg, earlier and smaller in subtropical areas. Migrates long distances upriver at beginning of a rapid flood and water-level increase (in April – July depending on locality). Spawns during floods. Stops spawning if conditions change and starts again with increase of water level. Spawns in upper water layer or even at surface. Females spawn up to 1.1 million eggs in 1–3 portions depending on duration of high-water period. Eggs are yellowish, transparent, and hatch after about 2 days at temperatures around 25°C while drifting downstream in the deep open-water layer. If the river flow is blocked or if available river stretches are too short, eggs cannot drift long enough and fail to develop. After spawning, adults leave the river and migrate to foraging habitats. Larvae drift downstream and settle in floodplain lakes, shallow shores and backwaters with little or no current. In autumn-winter, when temperatures falls to 10°C, juveniles and adults form separate large schools and move downstream to deeper places in main course of river to overwinter. Feeds mostly on zooplankton, also algae. Often crossed with *H. molitrix*.

Conservation status. Alien. In Europe survives only by stocking.

Further reading. Holčík, 1976: 90 (introduction, Danube); Movchan & Smirnov, 1983: 319 (morphology, biology).

Iberochondrostoma

This genus in endemic to the Iberian Peninsula. The species were earlier placed in *Chondrostoma* (see comments under this genus). They have a small size, a small mouth, without cornified sheath on lower lip, and inhabit slow flowing stretches of streams, with underwater vegetation. The published diagnoses of several species do not efficiently differentiate them and the following key is tentative.

Key to species of *Iberochondrostoma*

1a – Usually 43–47 + 2–3 lateral line scales. ..... *I. lusitanicum*

1b – Usually 45–59 + 2–3 lateral line scales. 2

2a – 45–49 + 2–3 lateral line scales. ..... *I. almacai*

2b – 49–59 + 2–3 lateral line scales. 3

3a – Eye diameter 1.0–1.5 times snout length. ..... *I. lemmingii*

3b – Eye diameter 0.7–1.0 times snout length. ..... *I. oretanum*

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Iberochondrostoma almacai; Torgal, Portugal; ~80 mm SL.

Iberochondrostoma lemmingii; Guadiana drainage, Spain; ~90 mm SL.

Iberochondrostoma almacai

Common name. Mira pardelha.

Diagnosis. Distinguished from other species of *Iberochondrostoma* by: ○ usually 45–49 + 2–3 lateral line scales / ○ usually 3½–4½ scale rows between lateral line and pelvic origin / ○ eye diameter about equal to snout length. Size up to about 130 mm SL.

Distribution. Southern Portugal: Mira, Arade and Bensafrim drainages.

Habitat. Ubiquitous. Small to medium sized streams. May be restricted to very small pools during summer. Spawns in shallow riffle habitats in fast-flowing water.

Biology. No data.

Conservation status. CR B2ab(i,ii,iii).

Further reading. Coelho et al., 2005: 206 (description).

Iberochondrostoma lemmingii

Common name. Pardilla.

Diagnosis. Distinguished from other species of *Iberochondrostoma* by: ○ usually 49–59 + 2–3 lateral line scales / ○ 4½–7 scale rows between lateral line and pelvic origin / ○ eye diameter 1.0–1.5 times snout length. Size up to about 120 mm SL.

Distribution. Tagus, Guadiana, Odiel, Guadalquivir (except Jándula system) and southwestern Douro drainages (Spain, Portugal).

Habitat. In middle reaches of streams, with mod-

Iberochondrostoma almacai

Iberochondrostoma lemmingii

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Iberochondrostoma lusitanicum; Samara, Portugal; ~100 mm SL.

Iberochondrostoma oretanum; Guadalquivir drainage, Spain; 88 mm SL.

erate current and abundant aquatic vegetation.
Biology. Feeds on algae and zooplankton. Apparently spawns in April – May.
Conservation status. VU A2ace + 3ce.
Further reading. Collares-Pereira, 1980a: 276 (description); Doadrio, 2001: 174 (biology, conservation status).

Iberochondrostoma lusitanicum

Common name. Portuguese pardelha.
Diagnosis. Distinguished from other species of *Iberochondrostoma* by: O eye diameter greater than snout length / O usually 43–47 + 2–3 lateral line scales / O 3½–5 scale rows between lateral line and pelvic origin. Size up to about 140 mm SL.
Distribution. Portugal: Sado, Lizandro, Samarra, Colares and Ossos drainages, south bank tributaries of Tagus.
Habitat. Middle and lower reaches of streams, with slow current and underwater vegetation.
Biology. Forms spawning aggregations involving large numbers of fishes. One female spawns with one or a few males, which press the female against the substratum and eggs are released. The movements attracts other individuals, which start spawning. The aggregation disperses after about 20–60 seconds and may form again several times. Eggs are adhesive.
Conservation status. CR A2ce. Populations reported to be sharply decreasing in recent years.
Further reading. Collares-Pereira, 1980a: 275 (description), 1980b: 151 (description, as *Chondrostoma arrigonis*); Carvalho et al., 2003 (reproduction); Coelho et al., 2005: 208 (description).

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Unisexual reproduction

In several species of fishes (and other animals), the sex-ratio is strongly skewed towards females. Males are missing or present in very low numbers (often around 1 %). These species are usually of hybrid origin and have developed mechanisms, which allow them to reproduce in the absence of males (or that allow them to perpetuate a male-free species as this is likely to be an ecological or evolutionary advantage under given local conditions, for example in making the hybrid species a better competitor against one or both parental species). The principal mechanisms are:

Hybridogenesis. An individual male or female of hybrid origin produces gametes from which one parental genome is eliminated during the gametogenesis. This way, for example, a female does not produce hybrid eggs but eggs with the genome of her mother only. The eggs are then fecundated by the sperm of a male, resulting in new F1 hybrids (if the male belongs to another species) or 'pure' individuals (if the male belongs to the same species as the genome remaining in the egg produced by the hybrid female).

Gynogenesis. An individual female produces eggs that are stimulated by the sperm of an other species. Here, there is no fecundation, the sperm only acts as trigger to initiate embryonic development.

Parthenogenesis. An individual female produces eggs, which develop without fertilization or stimulation by sperm.

Finally, **androgenesis** is not properly an unisexual mode of reproduction. As in the above cases the genome of a single sex is transmitted, but here it is the male genome. Androgenesis is a form of parthenogenesis in wich an individual female produces eggs without nucleus or without fusion of the egg and sperm nuclei. There is only the male nucleus in the egg.

Iberochondrostoma oretanum

Common name. Oretanian pardilla.

Diagnosis. Distinguished from other species of *Iberochondrostoma* by: ♦ 53–58 + 2–3 lateral line scales / ♦ 5–6 scale rows between lateral line and pelvic origin / ♦ eye diameter 0.7–1.0 times snout length. Size up to about 90 mm SL.

Distribution. Spain: Jándula system (Guadalquivir drainage).

Habitat. Clear water with sand and rock bottom, in stretches with slow current and underwater vegetation.

Biology. No data.

Conservation status. CR A2ace; B2ab(ii,iii). Small range seriously impacted by construction of a small dam and reservoirs, and introduction of alien species.

Further reading. Doadrio & Carmona, 2003: 30 (description).

Iberocypris

The genus *Iberocypris* includes 2 species from the Iberian Peninsula, which have been placed in the genera *Squalius* on the basis of introgressed mitochondria. They had at times also been placed in *Rutilus* or *Tropidophoxinellus*. Morphologically, both species are very distinct from *Squalius* species and share several character states with *Anaecypris* and *Alburnus*-like cyprinids (e.g. dark midlateral stripe, various osteological characters). *Iberocypris* are easily distinguished from *Squalius* by having fewer lateral line scales, a dark longitudinal stripe on the body (vs. absent) and a concave posterior margin of the anal (vs. straight to convex). *Iberocypris* are distinguished from *Anaecypris* in having a complete lateral line with 37–52 + 2–3 scales (vs. incomplete, perforating 2–23 scales out of 58–73 in midlateral row). The two included species form hybrid complexes with species of *Squalius*; there are indications that they have the same or closely related ancestors and therefore constitute a monophyletic genus, eventhough they 'parasitize' the genomes of other species. Hybridisation and DNA introgressions have led to mistinterpretation of the molecular data; additional data are needed to clarify the phylogenetic position of both species.

Iberocypris alburnoides

Common names. Calandino (Spain), bordalo (Portugal).

Diagnosis. Distinguished from other Cyprinidae in Iberian Peninsula by: ♦ no barbels / ♦ dark midlateral stripe from snout to caudal base / ♦ body slender, depth 3.8–4.4 times in SL / ♦ 37–42 + 2–3 lateral line scales / ♦ mouth opening upward / ♦ usually 8½ branched anal rays. Size up to about 70 mm SL for diploid, 110 mm SL for triploid individuals.

Distribution. Iberian Peninsula, in Douro, Tagus,

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Iberocypris alburnoides; Guadiana drainage, Portugal; diploid (*aa*) male, ~60 mm SL.

Iberocypris alburnoides; Guadiana drainage, Portugal; triploid female, ~90 mm SL.

Sado, Guadiana, Odiel, Guadalquivir and Quarteira drainages. Introduced in Júcar drainage.

Habitat. Ubiquitous.

Biology. Spawns in April – June. Feeds mainly on arthropods. A complex of populations including diploid, triploid and tetraploid males and females, with triploid females predominating in most populations. Different populations have different chromosomal structures and modes of reproduction. In most populations *I. alburnoides* (*a*) forms hybrids with *Squalius pyrenaicus* (*p*). Males and females *I. alburnoides* with two sets of *I. alburnoides* genomes (*aa*) undergo normal meiosis and produce haploid *I. alburnoides* gametes. *aa* males are abundant in Tagus and rivers south of it but absent in the Mondego and Douro drainages in the northern part of the species's range. *aa* females are very rare but are known at least in the Guadiana drainage. *aa* males are morphologically distinct from hybrid males and hybrid females; the morphology of *aa* females has not been described.

Where *I. alburnoides* hybridises with *Squalius pyrenaicus*, hybridisation may be restricted to male *S. pyrenaicus* mating with female *I. alburnoides*, or if present, male *I. alburnoides* may also hybridise with female *S. pyrenaicus*. Hybrids may be diploid, triploid or tetraploid with one, two or three copies of the *I. alburnoides* genome and one or two copies of the *S. pyrenaicus* genome. Most triploids are females and triploid females are the most abundant individuals in many localities. Hybrids with *paa*, *ppa*, *pa*, *paaa*, *ppaa* genomes ex-

Iberocypris alburnoides

Iberocypris palaciosi

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Iberocypris palaciosi; Guadalquivir drainage, Spain; 81 mm SL.

ist while *pppa* have not been found yet. All *I. albunoides* carry only *Squalius* mitochondria.

Hybrids have various modes of gamete formation. The diploid hybrids produce clonal eggs and may reproduce either by gynogenesis or the eggs may be fertilised and result in *ppa* or *paa* triploid hybrids. The *paa* triploids may reproduce by gynogenesis or by hybridogenesis, discarding the unpaired genome *p*, producing diploid but unreduced gametes *aa* or reduced gametes by normal meiosis and producing haploid gametes *a*. Individual hybrid females may produce more than one type of gametes and thus more than one type of offspring.

It has often been considered that females *I. alburnoides* use males of *Squalius* species as spawning partners and that the species is a sperm-parasite. It spawns with *S. pyrenaicus* in most of its range, with *S. carolitertii* in the Douro and Mondegon drainages in the north and with *S aradensis* in Quarteira drainage in the extreme south. While *I. alburnoides* females clearly are sperm parasite where males (hybrid or not) are absent or very rare as in the north of its range, it is likely that where males are present *I. alburnoides* populations are reproductively independent from *Squalius* species.

In most populations, *I. alburnoides* hosts the mitochondria of *S. pyrenaicus*, even in the northern part of its range where it co-occurs with *S. carolitertii*. In the Quarteira drainage it hosts mitochondria of the sympatric *S. aradensis*. The presence of mitochondria of *Squalius* in the genome of a given population of *I. alburnoides* seem to depend on the sex and chromosomal structure of the population. If males *I. alburnoides* are present and if they are able to produce (*a*) sperm they may produce hybrids. This seems to be the process allowing local introgression.

After triploid females were first discovered in 1983, there has been much discussion about the ancestors of these hybrids. *Squalius pyrenaicus* was identified first as the paternal and later as the maternal 'ancestor'. An unknown, probably extinct, paternal ancestor was hypothesized. Recent data show that this discussion was missleading. In fact, the 'missing ancestor' is *I. alburnoides* itself. It exists as 'pure' (*aa*) males in most populations at least in the southern part of its range. *I. alburnoides* is related to *Anaecypris* and *Alburnus*, a result long postulated by morphological studies.

I. alburnoides is not a species of hybrid origin. There is the species *I. alburnoides* and the various local hybrids with *Squalius*. It is more apropriate to see *I. alburnoides* as a species whose reproductive biology is deeply modified after hybridisation with *Squalius*, leading to an almost complete loss of non hybrid females. Future studies should test, whether these hybrids could allow the *I. alburnoides* genome to colonise or at least survive in habitats not suitable for *I. alburnoides* as a species, an interpretation put forward for the similar case of hybrid green frogs (*Rana*).

Conservation status. VU A3ce. Although widely distributed and locally abundant, the species is threatened by the introduction of exotic species (most of them piscivorous), habitat modification and water abstraction.

Further reading. Bogutskaya, 2000 (osteology, systematics); Sousa-Santos et al., 2006 (genetics); Robalo et al., 2006a (genetics); Alves et al., 2004 (genetics).

Iberocypris palaciosi

Common name. Bogardilla.

Diagnosis. Distinguished from *I. alburnoides* and species of *Squalius* in Iberian Peninsula by: ● 50–52 + 2–3 lateral line scales / ○ dark longitudinal stripe on body / ○ mouth subinferior / ○ posterior margin of anal concave. Size up to 200 mm SL.

Distribution. Spain: middle Guadalquivir drain-

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Ladigesocypris ghigii; Rhodos Island, Greece; 50 mm SL.

age near Andújar.

Habitat. Middle reaches of rivers, with abundant aquatic vegetation and moderate to fast current, with of rocks or gravel bottom.

Biology. Little information on biology. Spawns in April. Most individuals are females. Diploid, triploids and tetraploids genetically similar to that of *S. pyrenaicus* and *Iberocypris alburnoides*. Probably of hybrid origin and we suspect that the situation could be quite similar to that described for the *I. alburnoides* complex.

Conservation status. CR B1ab(ii,iii) + 2ab(ii,iii). Last known individual observed in 1999. Extirpated from most of its range by pollution and by water regulation.

Further reading. Doadrio, 1980: 7 (description), 2001: 208 (biology); Elvira, 1997 (biology).

Ladigesocypris ghigii

Common name. Gizani.

Diagnosis. Only native freshwater fish on Rhodos Island. Distinguished from other Cyprinidae in southeastern Europe by: ○ lateral line incomplete, perforating 11–17 scales / ○ 27–33 total scales in midlateral row / ○ 6–8½ branched dorsal rays / ○ 7–9½ branched anal rays / ○ broad dark midlateral stripe from head to caudal base, separating dark brown back from white belly. Size up to 65 mm SL in males, 90 mm SL in females.

Distribution. Greece: Rhodos Island.

Habitat. Springs, slow-flowing stretches of streams, especially roots of trees, bank cavities and among vegetation.

Biology. Lives up to 3 years. Spawns for the first time at 1 year. Spawns in February – June, depending on ecological characteristics of different water bodies and the condition of the spawners

Rhodos Island, Greece; natural habitat of *Ladigesocypris ghigii* and (background) shelter constructed to retain water in the dry season.

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Leucaspius delineatus; Rhine drainage, Germany; ~60 mm SL.

(due to the harsh unstable habitat). Fractional spawner. Spawns among aquatic vegetation, especially filamentous algae. Eggs adhesive, 1.3 mm in diameter, hatch in 4 days. Larvae along banks among vegetation. Feeds on small aquatic invertebrates and algae, in summer mainly on plant material. Large number of juveniles and adults die every year during summer and autumn drought.

Conservation status. VU D2. Was threatened by water abstraction in the dry season and habitat destruction. Ongoing conservation project supported by EU Life-Nature program seems to result in the successful protection of at least some populations.

Remarks. Other species of *Ladigesocypris* from Turkey are distinguished as follow: *L. irideus* from Bergama to Dalaman has 5–11 pored scales on lateral line; *L. mermere* from Lake Marmara has 29–35 total scales in midlateral row, 21–27 pored scales along lateral line.

Further reading. Bogutskaya, 1996: 39 (description); Stoumboudi et al., 2002a: 178 (reproduction, conservation), 2002b (conservation).

Leucaspius delineatus

Common name. Sun bleak.

Diagnosis. Only species of genus. Distinguished from other Cyprinidae in central and eastern Europe by: ○ incomplete lateral line with about 8–12 pored scales / ○ keel covered by scales between pelvic origin and anus / ○ mouth superior / ○ 11–13½ branched anal rays. Size up to about 90 mm SL.

Distribution. From lower Rhine and northern Germany eastward to southern Baltic basin; Black Sea basin south to Rioni drainage, northern and western Caspian basin (south to Kura drainage); Aegean Sea basin (from Maritsa to Nestos). Absent in Italy, Adriatic basin, Great Britain and Scandinavia (except southernmost Sweden). Widely introduced in France, upper Rhine drainage and locally in Great Britain and Switzerland.

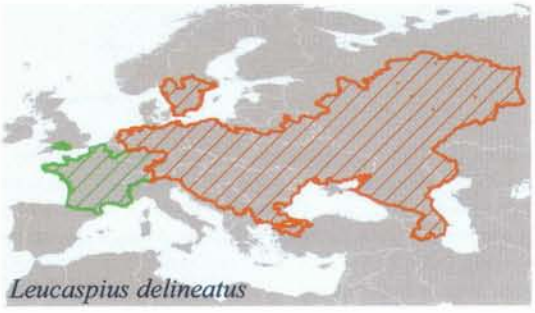
Habitat. Lowland riverine habitats especially oxbows and other water bodies only connected to rivers during floods. Often found in ponds, steppe lakes and small water bodies not connected to rivers. May occur in any habitat with few or no predators.

Biology. Gregarious. Spawns for the first time at 1 year; spawns only for a single season. Spawns in May – September, when temperature reaches 16–18°C. Females may spawn about once every three weeks. Males are territorial; they clean the spawning site and guard the eggs, which are attached in strings around roots, reeds, aquatic vegetation or any material drifting on the water surface. Feeds mostly on zooplankton and terrestrial insects. Stunted populations may form in predator-free habitats. Often quickly reaches newly-created water bodies by still unknown mechanisms. Scales were used to produce Essence d'Orient, which was used for coating artificial pearls.

Conservation status. LC. Locally threatened by draining of wetlands.

Further reading. Arnold & Längert, 1995 (biology).

Ladigesocypris ghigii



Leucaspius delineatus

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Leuciscus

Species of *Leuciscus* are characterised by their silvery, elongated body, the concave posterior margin of the anal, the complete lateral line and 7–8½ branched dorsal rays. Most live in streams with clear water and moderate to swift current. Many species previously placed in *Leuciscus* are now in the genera *Squalius*, *Telestes* and *Petroleuciscus*.

Key to species of *Leuciscus* in Europe

1a – 56–58 + 3 lateral line scales; 10–11½ branched anal rays; 3.5–5.3 pharyngeal teeth. ..... *L. idus*

1b – 37–52 + 2–3 lateral line scales; 8–10½ branched anal rays; 2.5–5.2 pharyngeal teeth. 2

2a – Articulation of lower jaw in front of or below anterior margin of eye (Fig. 44a); 35–41 + 2–4 lateral line scales; horizontal branch of preoperculum as long as or slightly longer than vertical branch (Fig. 44c). ..... *L. danilewskii*

2b – Articulation of lower jaw distinctly behind anterior margin of eye; 41–53 + 1–3 lateral line scales; horizontal branch of preoperculum shorter than vertical branch (Fig. 44b). 3

3a – Jaws subequal, upper jaw slightly longer; snout not projecting; tip of upper lip about level with centre of eye; lips thin. ..... *L. leuciscus*

3b – Upper jaw distinctly longer than lower jaw; snout projecting; tip of upper lip at or below level of lower margin of eye; lips thick, fleshy. 4

4a – A keel from nape to dorsal origin; tip of snout rounded; eye diameter 22–26 % HL; dorsal profile of head and body not continuously rounded, with distinct hump. ..... *L. bearnensis*

4b – No keel between nape and dorsal origin; tip of snout pointed; eye diameter 19–21 % HL; dorsal profile of head and body regularly rounded, continuous, usually no marked hump. 5

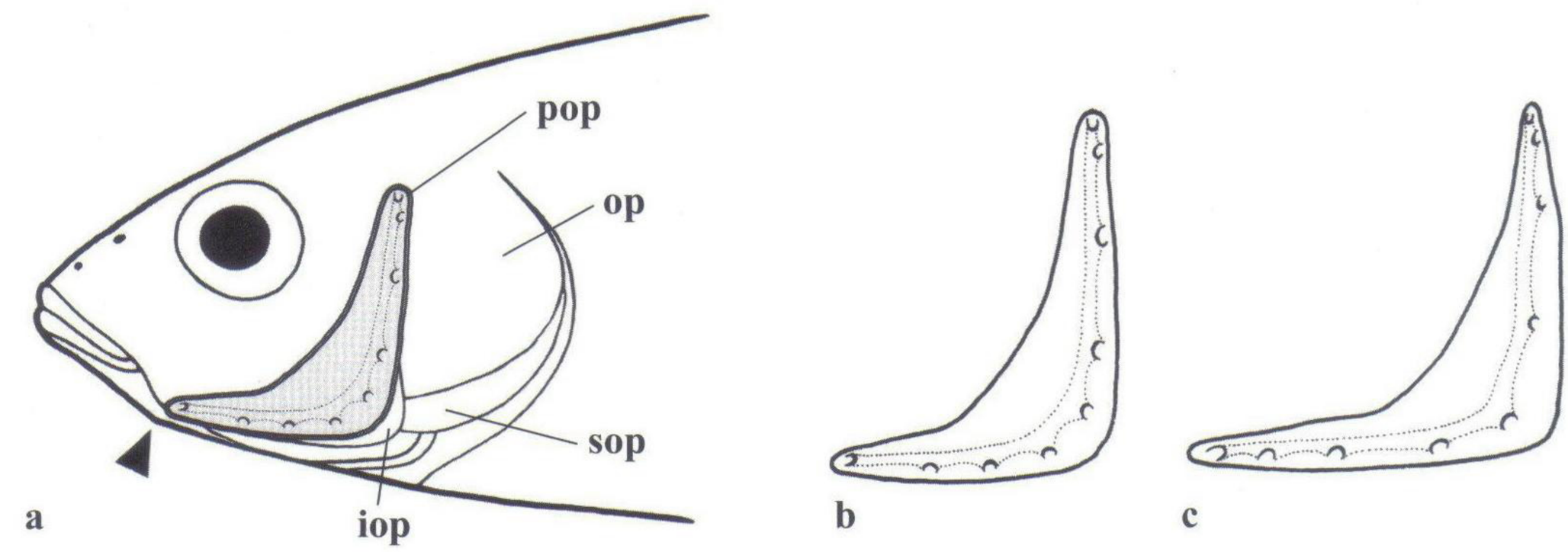

Figure 44 Head of leuciscine species: **a,** position of preoperculum (shaded) and articulation of lower jaw (arrow). The preoperculum is the 'cheek' bone bearing the posterior part of the sensory canal, which ends at posterior tip of lower jaw. The articulation of the lower jaw roughly corresponds to the anterior extremity of the preoperculum and is usually visible through the skin, sometimes protruding through the skin or observable by moving the jaw; **b,** *Leuciscus leuciscus*; **c,** *L. danilewskii*. **iop,** interoperculum; **op,** operculum; **pop,** preoperculum; **sop,** suboperculum.

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Leuciscus bearnensis; Adour, France; 230 mm SL.

Leuciscus burdigalensis; Loire drainage, France; 158 mm SL.

5a – 47–49 + 3 lateral line scales; snout length 32–34 % HL; tip of upper lip at level of lower margin of eye.
..... *L. burdigalensis*

5b – 49–53 + 2–3 lateral line scales; snout length 33–38 % HL; tip of upper lip below level of lower margin of eye.
..... *L. oxyrrhis*

Leuciscus bearnensis

Common name. Bearn beaked dace.

Diagnosis. Distinguished from other species of *Leuciscus* in western Europe by: ● keel from nape to dorsal origin / ○ snout projecting, pointed, tip rounded / ○ upper jaw projecting / ● dorsal profile of head and body not continuously rounded, with distinct hump / ○ lips thick, fleshy / ○ eye diameter 22–26 % HL / ○ snout length 32–35 % HL / ○ 47–52 + 2–3 lateral line scales. Size up to about 280 mm SL.

Distribution. France: Adour drainage.

Habitat. Streams, sectors with current, clear and cool water, in deep pools.

Biology. No data.

Conservation status. LC*.

Further reading. Spillmann, 1961: 145 (biology); Kottelat, 1997: 64 (systematics).

Leuciscus burdigalensis

Common name. Beaked dace.

Diagnosis. Distinguished from other species of *Leuciscus* in western Europe by: ○ no keel from nape to dorsal origin / ○ snout projecting, pointed / ○ upper jaw projecting / ○ dorsal profile of head and body continuously rounded, usually no marked hump / ○ lips thick, fleshy / ○ eye diameter 19–21 % HL / ○ snout length 32–34 % HL / ○ 47–49 + 3 lateral line scales. Size up to about 400 mm SL.

Distribution. France: from Loire to Garonne drainages on Atlantic slope, from Tech to Aude drainages on Mediterranean slope. *Leuciscus* population from Hérault possibly conspecific.

Leuciscus bearnensis

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Leuciscus danilewskii; lower Don, Russia; ~90 mm SL. A. Naseka

Habitat. Streams and rivers, sectors with current, clear and cool water, in deep pools.
Biology. Adults apparently undertake small migrations. Spawns in February – March, at night, in stretches with swift current and pebble bottom, in deeper pools.
Conservation status. LC.
Further reading. Spillmann, 1961: 145 (diagnosis, biology); Kottelat, 1997: 64 (systematics); Chappaz et al., 1998 (genetics); Costedoat et al., 2006 (genetics).

Leuciscus danilewskii

Common name. Don dace.
Diagnosis. Distinguished from other species of *Leuciscus* in Europe by: ○ mouth subinferior or subterminal, jaws subequal, upper jaw slightly longer / ○ tip of upper lip about level with centre of eye / ○ snout not projecting / ○ articulation of lower jaw in front of or below anterior margin of eye / ● horizontal branch of preoperculum as long as or slightly longer than vertical branch (Fig. 44c) / ○ 35–41 + 2–4 lateral line scales. Size up to 240 mm SL.
Distribution. Don drainage.
Habitat. Prefers main course of rivers, with clear water, moderate to slow current, sand or sand-clay bottom. Avoids turbid and still waters. Commonly stays on bottom, in water 0.3–3 m deep. Spawns in stretches with heavy current and stone bottom.
Biology. Forms small groups of individuals of similar size. Lives up to 7 years. Spawns in April – May at 5–6°C. Eggs are 2.0 mm in diameter, sticky, slightly transparent. Eggs hatch in 9 days at 13°C. Larvae lack adhesive glands, lie passively on bottom. Starts active feeding at 16 days. Feeds mainly on insects and their larvae, molluscs, also on other benthic invertebrates and algae.
Conservation status. LC.
Remarks. Records of *L. leuciscus* from Don drainage probably refer to *L. danilewskii*.
Further reading. Movchan & Smirnov, 1981 (description, biology); Bogutskaya, 1987 (description, systematics).

Leuciscus idus

Common name. Ide.
Diagnosis. Distinguished from other species of *Leuciscus* in Europe by: ● 56–58 + 3 lateral line scales / ● 3,5–5,3 pharyngeal teeth / ○ mouth terminal / ○ 8½ branched dorsal rays / ○ 10–11½ branched anal rays / ○ all fins except dorsal with reddish tinge / ○ pigmentation on lateral scales without regular black mesh. Size up to 850 mm SL, usually about 350–400 mm SL. A golden variety commonly introduced in urban habitats.
Distribution. Baltic, Black, northern Caspian and North Sea basins, Atlantic basin southward to Seine and lower Loire drainages (France). Absent in Scandinavia north of 69°N. In Asia, eastward to Lena drainage and Aral basin. Introduced to Great Britain and northern Italy.
Habitat. Usually in large lowland rivers and nutrient-rich lakes. Migrates to tributaries for spawning in moderate current on gravel or submerged vegetation.
Biology. Juveniles gregarious, adults more solitary. Lives up to 15 years. Spawns for the first

Leuciscus burdigalensis

Leuciscus danilewskii

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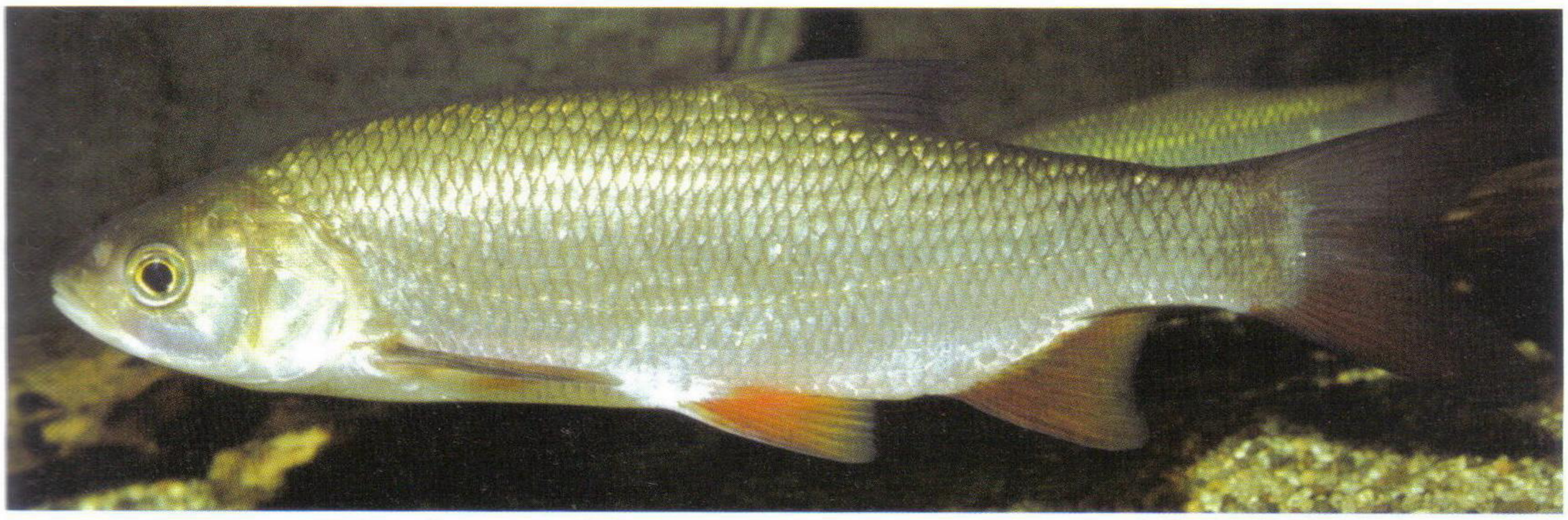
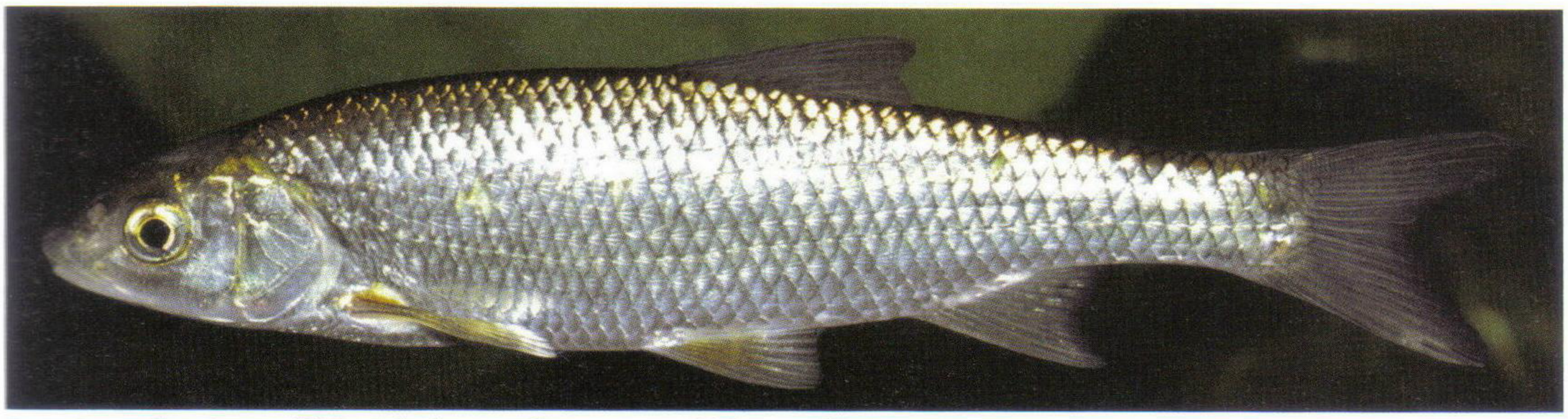


Leuciscus idus; lower Rhine, Germany; ~350 mm SL.



Leuciscus leuciscus; Rhine drainage, Germany; ~110 mm SL.

time at 5–6 years. Spawns in March – April, when temperature rises above 10°C. Females spawn only once each season. Adults often undertake long spawning migrations. Individual females spawn with several males. Males assemble at spawning grounds and follow ripe females. Females attach the sticky eggs to gravel or submerged plant material. Feeding larvae and juveniles inhabit a wide variety of shoreline habitats. They leave the shores for deeper waters when growing. Reaches up to 130 mm SL during first year. Feeds on a wide variety of aquatic and terrestrial animals and plant material. Large individuals become predominantly piscivorous. Sometimes hybridises with *Aspius aspius*.

Conservation status. LC.

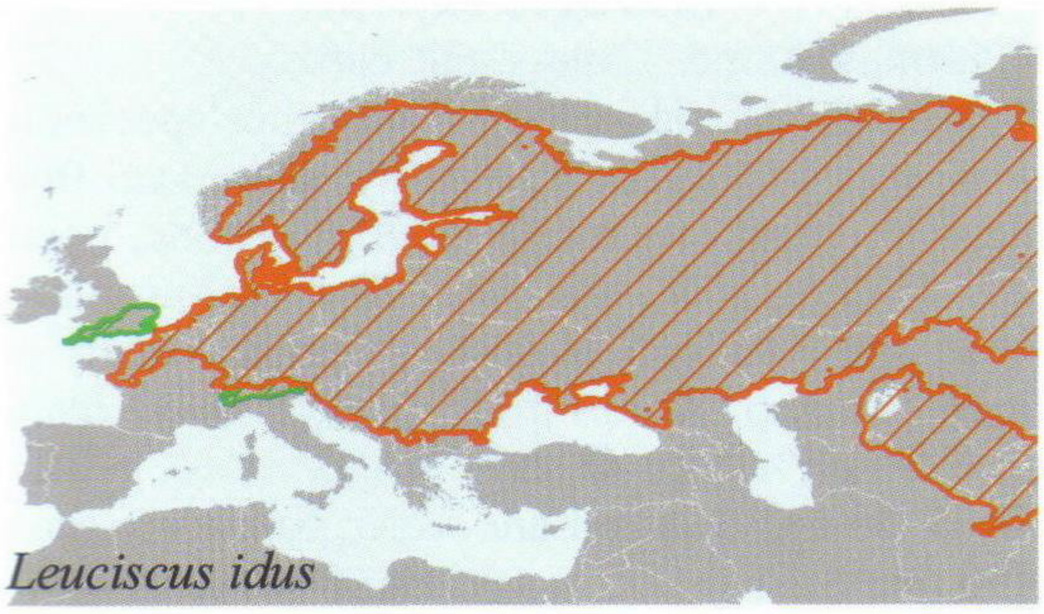
Further reading. Brabrand, 1985 (biology).

Leuciscus leuciscus

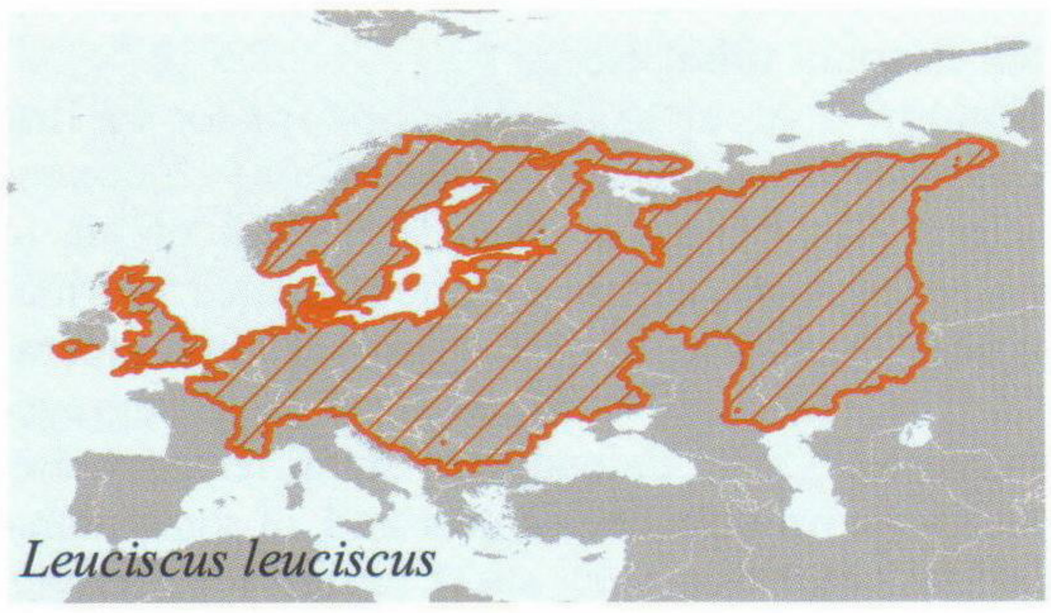
Common name. Dace.

Diagnosis. Distinguished from other species of *Leuciscus* in Europe by: ❶ mouth subinferior or subterminal, jaws subequal, upper jaw slightly longer / ❶ tip of upper lip about level with centre of eye / ❶ snout not projecting / ❶ articulation of lower jaw distinctly behind anterior margin of eye / ❶ horizontal branch of preoperculum shorter than vertical branch (Fig. 44b) / ❶ 41–50 + 1–2 lateral line scales. Size up to 250 mm SL.

Distribution. North, Baltic, White and Barents Sea basins; Caspian basin, in Volga and Ural drainages; Black Sea basin, from Danube to Dniepr drainages; Atlantic basin, in Seine drainage; Mediterranean basin from Rhône to Arc drainages (France). Only very localised in Danube main river in Romania, in Scandinavia north of 69°N and most of central Finland.



Leuciscus idus



Leuciscus leuciscus

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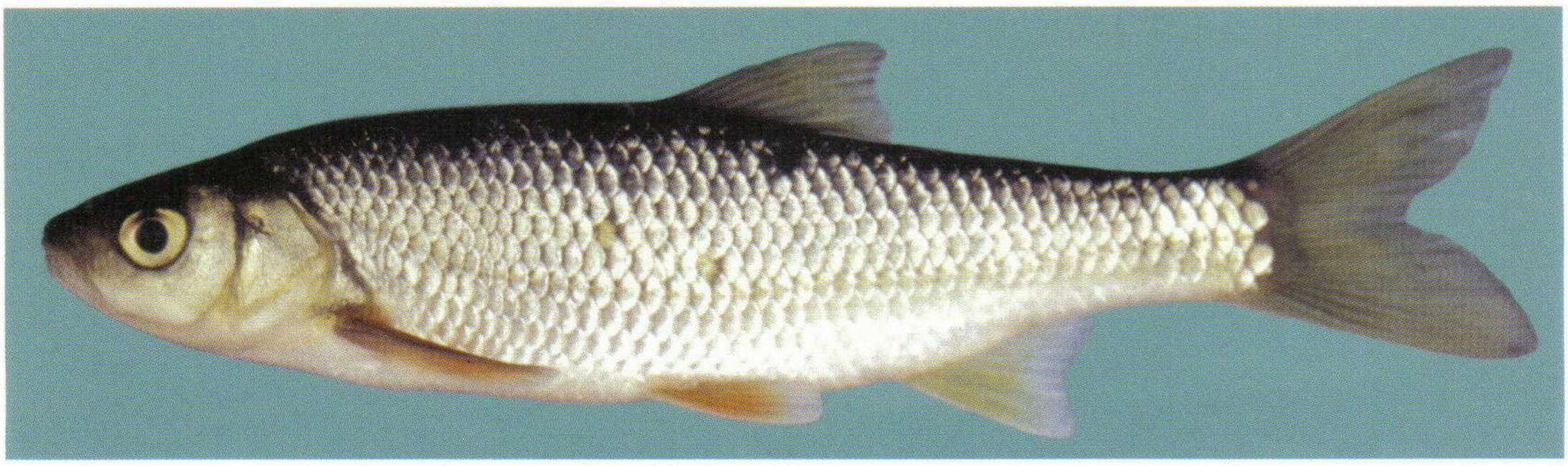
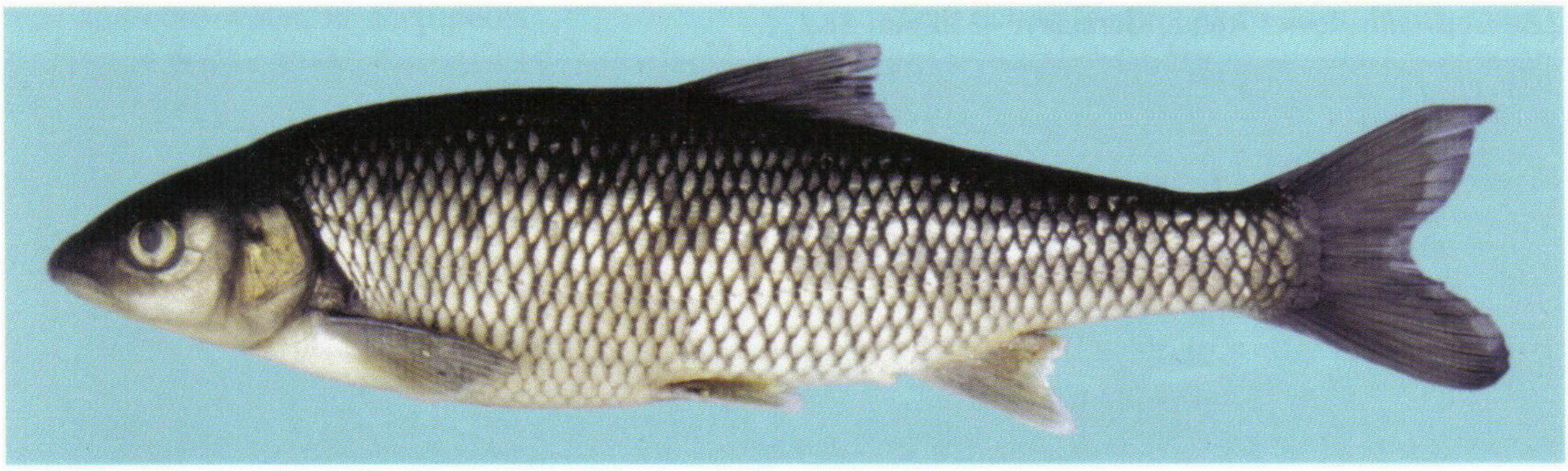
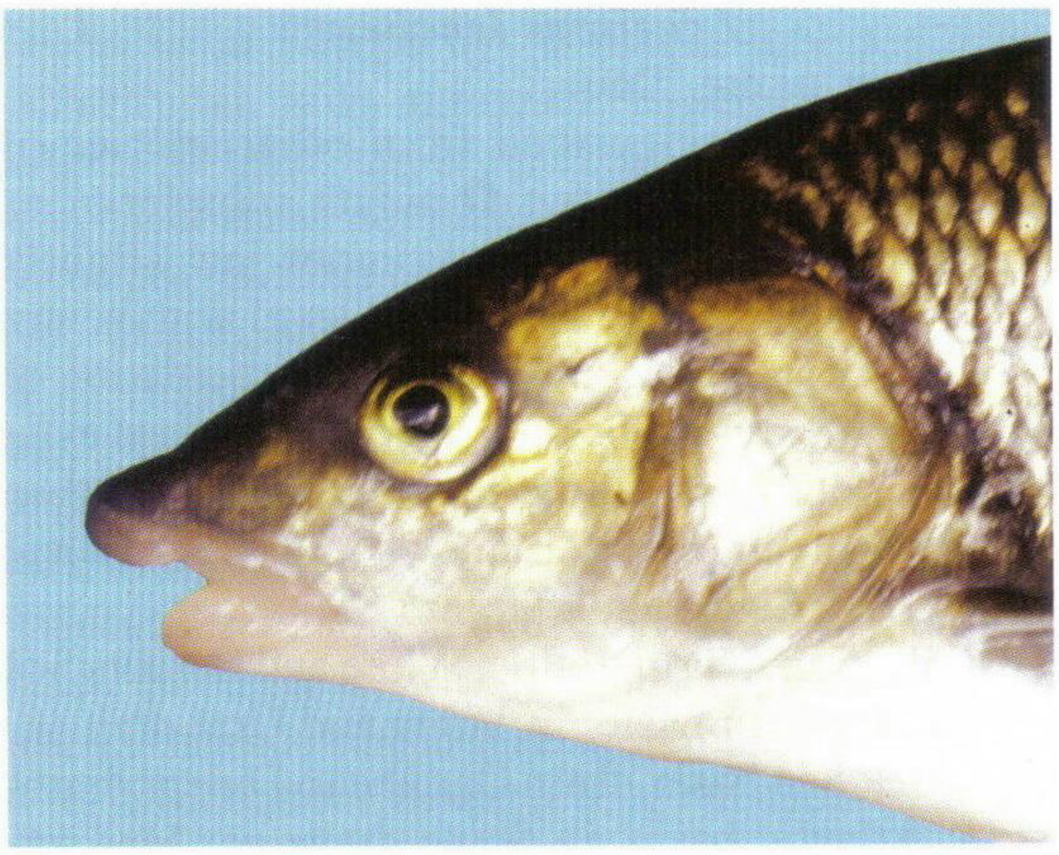


Leuciscus leuciscus; Rhône drainage, France; 146 mm SL.



Leuciscus oxyrrhis; Dourbie, Tarn system, France; 230 mm SL.



Leuciscus oxyrrhis; Dourbie, Tarn system, France; ~400 mm SL.

Habitat. Moderate to fast-flowing large streams to large rivers with rock or gravel bottom. Spawns in fast-flowing water on shallow gravel beds, often in small tributaries.

Biology. Lives up to 10 years. Spawns for the first time at 3 years. Usually spawns only 1–2 seasons during life. Migrates often some tens of km to spawning sites, which are often situated in tributaries. Spawns in March – April when temperatures reache 8–10°C. Males form large aggregations, each male defending a small territory. Females spawn only once a year and, in some populations, during a very short period (3–5 days). Females deposit the sticky eggs into excavations made in gravel. Feeding larvae live along shores. Early juveniles are benthic and inhabit very shallow shoreline habitats. When growing, they leave the shores for faster-flowing waters. They reach up to 85 mm SL during first year. Year class strength is closely related to high spring temperatures and absence of spring floods. Juveniles overwinter in cavities along the shores. Adults form dense swarms during winter in lower parts of rivers or in backwaters. Often migrates to spawning streams in autumn and overwinter there. Feeds on small invertebrates.

Conservation status. LC.

Remarks. Siberian and East Asian populations usually referred to *L. leuciscus* are distinct species, *L. baicalensis* and *L. dzungaricus*.

Further reading. Wüstemann & Kammerad, 1995 (biology).

Leuciscus oxyrrhis

Common name. Long-snout dace.

Diagnosis. Distinguished from other species of *Leuciscus* in western Europe by: O no keel from nape to dorsal origin / O snout projecting, pointed / O upper jaw projecting / O dorsal profile of head and body continuously rounded, usually no marked hump / O lips thick, fleshy / O eye diameter 19–21 % HL / O snout length 33–38 % HL / O 49–53 + 2–3 lateral line scales. Size up to about 400 mm SL.

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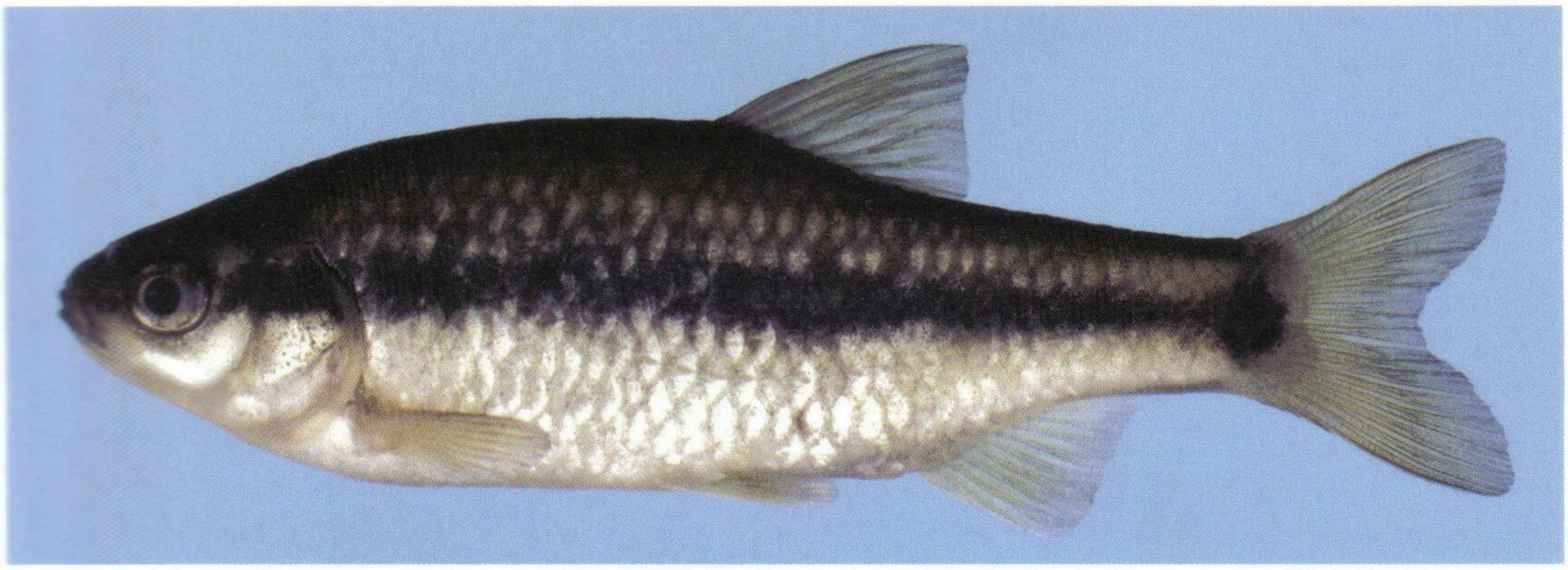


Pachychilon macedonicum; Vardar drainage, Greece; 64 mm SL.

Distribution. France: upper reaches of Lot, Aveyron, Tarn and Dordogne (Garonne drainage).
Habitat. Streams and rivers, sectors with current and clear water, in deep pools.
Biology. Feeds on vegetal matter. Spawns in March – April in stretches with swift current and pebble bottom.
Conservation status. LC.
Remarks. The taxonomic status of this species requires further investigation.
Further reading. La Blanchère, 1873: 662 (description).

Pachychilon

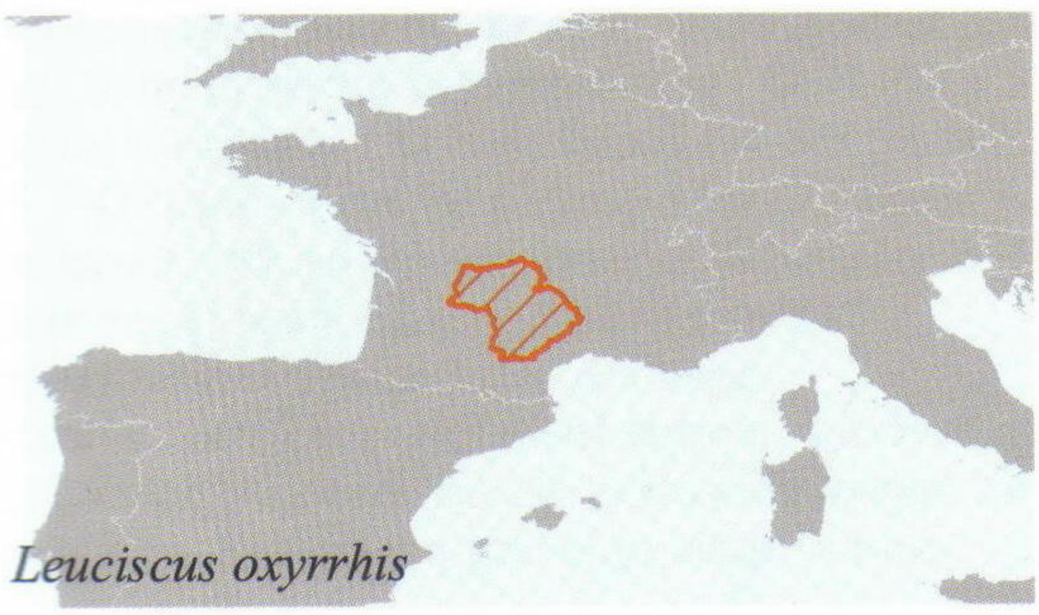
The two species of *Pachychilon* are distinguished by the shape of the lower lip, with a continuous postlabial groove and two median longitudinal incisions delimitating a more or less developed median lobe (Fig. 36); the lips are thicker and the lobe well developed in *P. pictum* while it is only feebly marked in *P. macedonicus*. The anterior part of the upper lip is covered by the fleshy overhanging rostral cap, more developed in adults, and especially conspicuous in *P. pictum*.

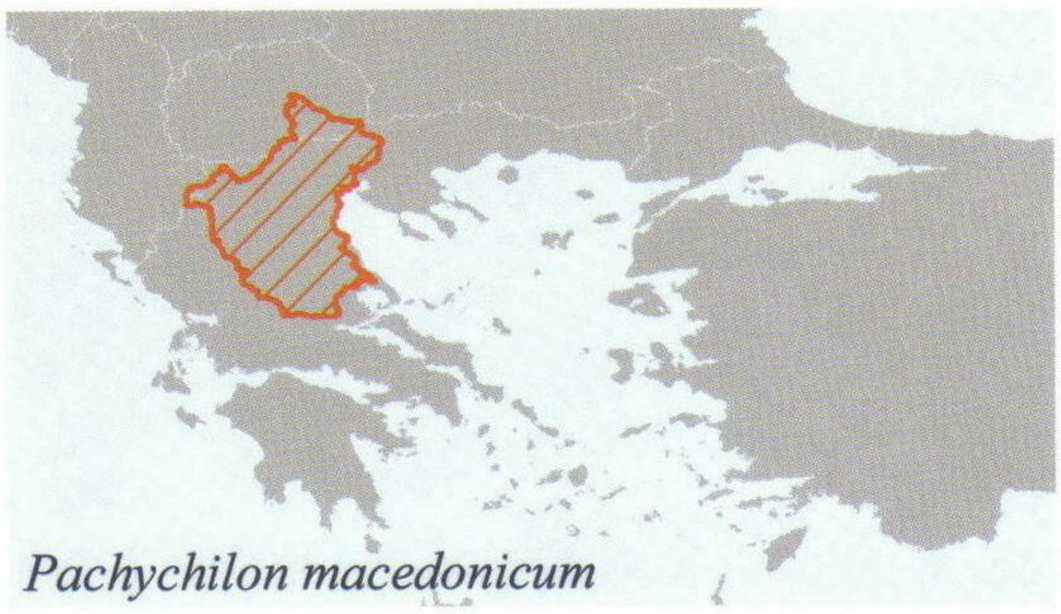
Pachychilon macedonicum

Common name. Mavrotsironi.
Diagnosis. Distinguished from *P. pictum* by: ● broad black stripe from tip of snout to middle of caudal base, separating silvery belly from dark brown dorsum / ● a vertically elongated black blotch at caudal base (stripe and blotch hardly distinct in life) / ● lower lip with a small squarish median lobe / ● 35–39 + 2 lateral line scales / ○ 7–8½ branched anal rays. Size up to 120 mm SL.
Distribution. From Gallikos to Pinios drainages (Greece, Macedonia).
Habitat. Slow-flowing or still waters, lakes.
Biology. Spawns in May – June.
Conservation status. DD.
Further reading. Steindachner, 1892: 377 (description); Šorić, 1992 (morphology).

Pachychilon pictum

Common name. Moranec.
Diagnosis. Distinguished from *P. macedonicum* by: ● body with numerous dark brown marks of various shapes and sizes (a dark stripe distinct in life in juveniles, rarely in preserved individuals) / ● lower lip thick, with a long median lobe (Fig. 36) / ● 40–44 + 2 lateral line scales / ○ 8–10½





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Pachychilon macedonicum; Pinios (Thessaly) drainage, Greece; 78 mm SL.

Pachychilon pictum; Moraca, Drin drainage, Montenegro; ~120 mm SL.

branched anal rays. Size up to 180 mm SL.

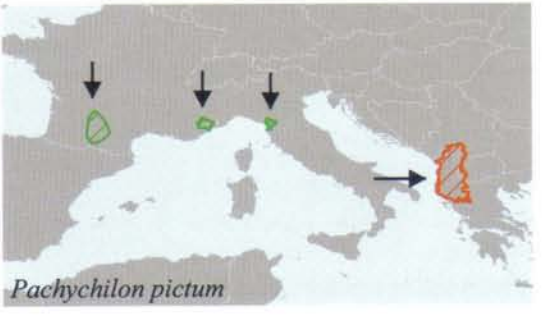
Distribution. Adriatic basin, from Drin to Aoos drainages. Introduced (apparently mixed with bait or fry) in Serchio (Italy), Garonne and Var (France) drainages, and probably elsewhere.

Habitat. In lakes, near shores. In streams and rivers, in slow-flowing stretches and backwaters.

Biology. Gregarious. Spawns in March – June over gravel beds or among vegetation, at temperatures above 12°C. Eggs adhere to substrate. Feeds on insect larvae and periphyton.

Conservation status. LC.

Further reading. Karaman, 1924: 34 (description); Dimovski & Grupče, 1974b (morphology); Ivanovic, 1973: 82 (biology); Šorić 1992 (systematics).



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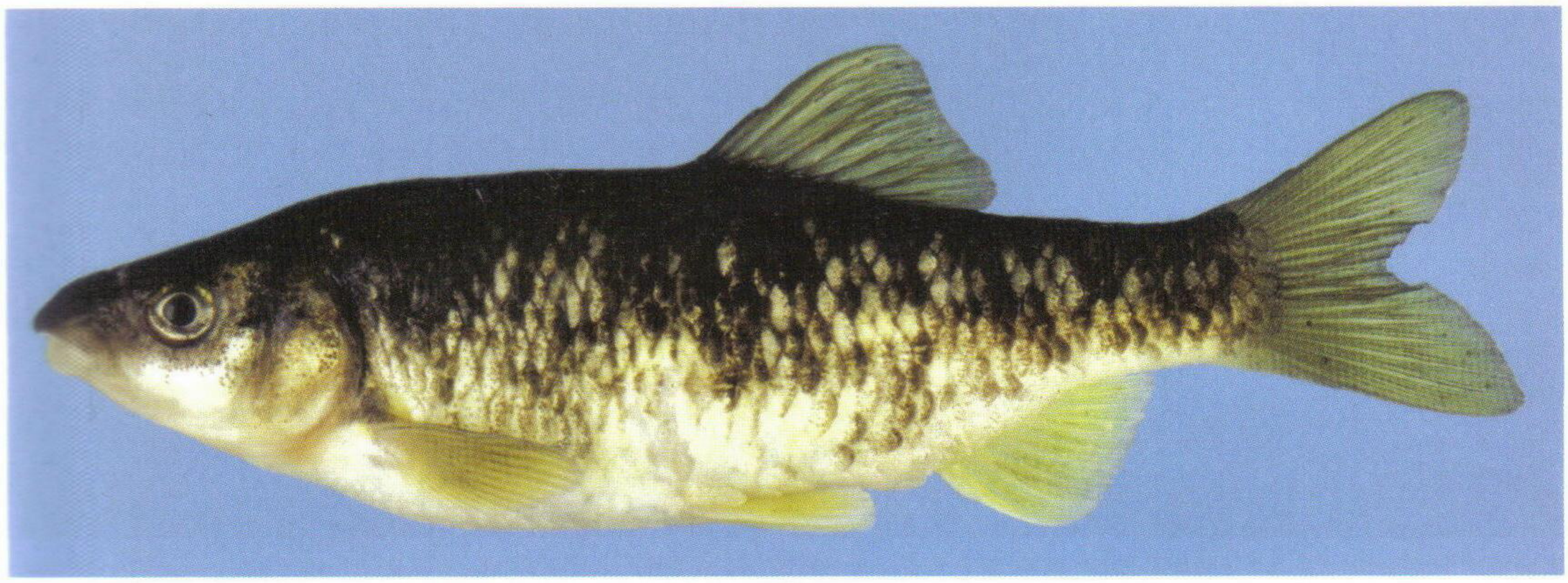


Pachychilon pictum; Lake Ohrid, Macedonia; 128 mm SL.

Parachondrostoma

This genus in endemic to the Iberian Peninsula and the Rhône and Garonne drainages. The species were earlier placed in *Chondrostoma* (see comments under this genus). The published diagnoses of several species do not efficiently differentiate them and the following key is tentative.

Key to species of *Parachondrostoma*

1a – 16–23 gill rakers (Jucar drainage).
..... *P. arrigonis*

1b – 21–35 gill rakers.
..... 2

2a – Snout pointed; depth of caudal peduncle 2.0–2.3 times in its length (Rhône and Garonne drainages).
..... *P. toxostoma*

2b – Snout blunt or sligthly pointed; depth of caudal peduncle 1.5–2.0 times in its length.
..... 3

3a – Snout slightly pointed, rostral cap visible in ventral view; 45–56 + 3–4 lateral line scales; usually 7–6 (rarely 6–6) pharyngeal teeth (Ebro and eastern Cantabric drainages).
..... *P. miegii*

3b – Snout blunt, rostral cap hidden by upper lip in ventral view; 41–48 + 3 lateral line scales; usually 6–5 (rarely 6–6) pharyngeal teeth (Turia and Mijares drainages).
..... *P. turiense*

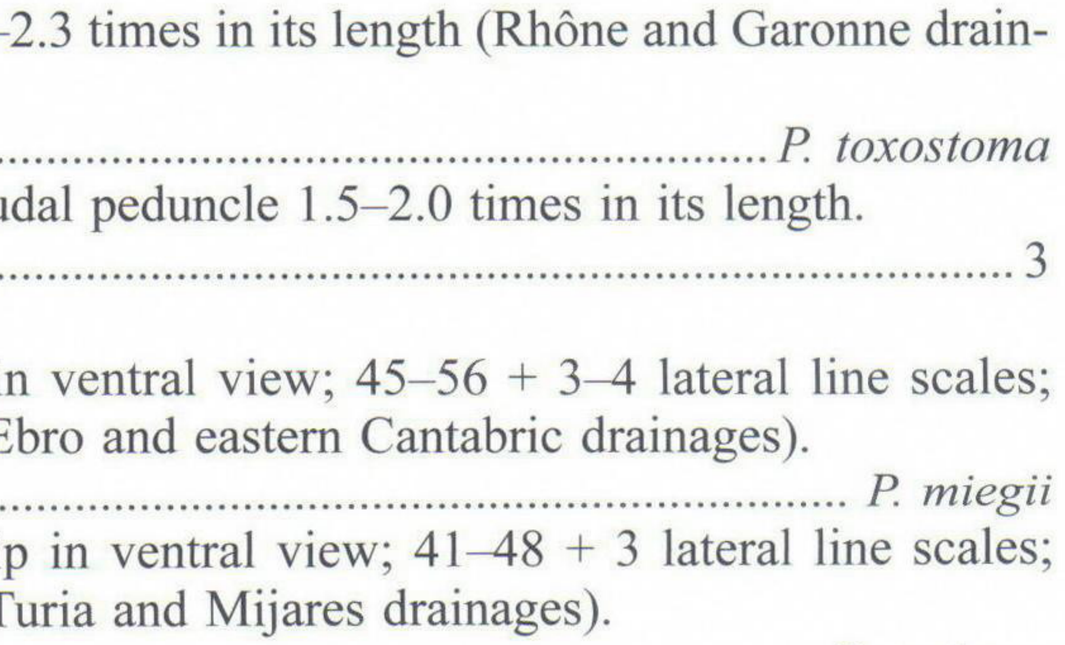
Parachondrostoma arrigonis

Common name. Loina.

Diagnosis. Distinguished from other species of *Parachondrostoma* by: ❍ snout blunt, rostral cap hidden by upper lip in ventral view / ❍ 41–50 + 3 lateral line scales / ❍ body depth 4.4–5.6 times in SL / ❍ depth of caudal peduncle 1.9–2.2 times in its length / ❍ 16–23 gill rakers / ❍ usually 6–5 pharyngeal teeth. Size up to 250 mm SL.

Distribution. Spain: Jucar drainage.

Habitat. Stretches with swift current, survives in still water but needs access to flowing waters for spawning. Spawns on gravel to stone bottom.



Parachondrostoma arrigonis

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Parachondrostoma arrigonis; Jucar drainage, Spain; ~80 mm SL. L. Kalous

Parachondrostoma miegii; Ebro drainage, Spain; ~120 mm SL.

Biology. Limited information. Rheophilic, moves to upper parts of drainage for spawning in March – May.

Conservation status. CR A2ace; B2ab(i,ii,iii, iv,v). Very sharp decline in last 20 years. Extirpated in most of Jucar drainage following invasion of *Pseudochondrostoma polylepis*, which seems to be a strong competitor. Apparently survives only in one headwater where a dam prevents penetration of *P. polylepis*.

Further reading. Elvira, 1987: 131 (systematics); Doadrio, 2001: 170 (biology).

Parachondrostoma miegii

Common name. Ebro nase.

Diagnosis. Distinguished from other species of *Parachondrostoma* by: ○ snout slightly pointed, rostral cap distinct in ventral view / ○ 45–56 + 3–4 lateral line scales / ○ body depth 3.7–4.4 times in SL / ○ depth of caudal peduncle 1.5–1.9 times in its length / ○ 24–33 gill rakers / ○ 7–6 or 6–6 pharyngeal teeth. Size up to 250 mm SL.

Distribution. Spain: eastern Cantabric slope, Ebro and adjacent drainages in northeast, and one adjacent headwater in Tagus drainage.

Habitat. Fast-flowing stretches, survives in still water. Spawns on stone and gravel bottom.

Biology. Rheophilic. Spawns for the first time at 2–3 years. Moves towards upper stretches for spawning, in April – June. Feeds on benthic diatoms.

Conservation status. LC.

Further reading. Elvira, 1987: 133 (systematics), Doadrio, 2001: 177 (biology).

Parachondrostoma miegii

Parachondrostoma toxostoma

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Parachondrostoma toxostoma; Rhône drainage, France; 150 mm SL.

Parachondrostoma turiense; Turia drainage, Spain; 146 mm SL.

Parachondrostoma toxostoma

Common name. Toxostome.

Diagnosis. Distinguished from other species of *Parachondrostoma* by: ❍ snout pointed, rostral cap distinct in ventral view / ❍ 50–59 + 3–4 total lateral line scales / ❍ body depth about 3.8–4.4 times in SL / ❍ depth of caudal peduncle about 2.0–2.3 times in its length / ❍ 24–35 gill rakers / ❍ usually 6–6 pharyngeal teeth. Size up to about 300 mm SL.

Distribution. Rhône (except Lake Geneva basin), Var, Hérault, Aude, Garonne and Adour drainages (France, Switzerland); invasive in Loire and Seine drainages.

Habitat. Streams with fast, clear water, with cobble bottom. Spawns on gravel and stony banks in fast waters.

Biology. Lives up to 10 years. Spawns for the first time at 3–4 years. Spawns in May – June, in large schools. Eggs hatch in about 8 days at 15°C. Feeds on invertebrates and algae.

Conservation status. VU A2ce. Extirpated in most of Rhône drainage due to invasion of *Chondrostoma nasus*, which seems to be a strong competitor. Apparently survives only where weirs and dams prevent penetration by *C. nasus*. Constructions of fish passes will allow invasion of last refuges.

Further reading. Elvira, 1987: 131 (systematics); Maier et al., 1995: 42 (biology); Gozlan & Chappaz, in Keith & Allardi, 2001: 174 (biology, distribution).

Parachondrostoma turiense

Common name. Madrija.

Diagnosis. Distinguished from other species of *Parachondrostoma* by: ❍ snout blunt, rostral cap hidden by upper lip in ventral view / ❍ 41–48 + 3 lateral line scales / ❍ body depth about 3.8–4.2 times in SL / ❍ depth of caudal peduncle about 1.7–1.9 times in its length / ❍ 21–27 gill rakers / ❍ 6–6 or 6–5 pharyngeal teeth. Size up to 250 mm SL.

Distribution. Spain: Turia and Mijares drainages.

Habitat. Stretches with swift current, survives in still water but needs access to flowing waters for spawning. Spawns on gravel to stone bottom.

Biology. Rheophilic, moves to upper parts of drainages for spawning in March – May.

Conservation status. EN B2ab(i,iii,v).

Further reading. Elvira, 1987: 182 (systematics); Doadrio, 2001: 182 (biology).

Parachondrostoma turiense

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Pelasgus

Species of *Pelasgus* are small-sized fishes found in springs, small and shallow creeks, backwaters, and ditches in the Balkan Peninsula. They were earlier placed in *Pseudophoxinus*, which includes numerous species in Asia Minor, Levant, Algeria and Tunisia. They are able to survive the summer droughts in the few pools that remain in the river beds, in springs or in wells. In the semi-arid to arid peri-Mediterranean environments, aquatic habitats are very much fragmented and this lead to geographic isolation and speciation, resulting in a number of species with ranges restricted from one to a few hydrographic basins. Species of *Pelasgus* have an incomplete lateral line, sometimes missing altogether; the scales tend to be partly embedded in the skin or covered by well exposed scale pockets.
Further reading. Bogutskaya, 1992, 1997 (systematics; *Pseudophoxinus*); Kottelat & Barbieri, 2004 (systematics); Kottelat & Freyhof, 2007a (systematics).

Keys to species of *Pelasgus*

1a – 58–73 + 2 scales in midlateral row; scales very small, not overlapping, deeply embedded in skin (Lakes Prespa).
..... *P. prespensis*

1b – 35–58 + 1–2 scales in midlateral row; scales overlapping, distinct, with or without scale pockets covering part of them (Fig. 45).
..... 2

2a – 53–58 + 2 scales in midlateral row; 16–23 pored lateral line scales (Lake Pamvotis).
..... *P. epiroticus*

2b – 35–48 + 1–2 scales in midlateral row; 0–14 pored lateral line scales.
..... 3

3a – 6–6½ branched anal rays (Peloponnese).
..... *P. laconicus*

3b – 7–7½ branched anal rays.
..... 4

4a – Depth of caudal peduncle about 1.8–2.0 times in its length (Lake Ohrid and Drin drainage).
..... *P. minutus*

4b – Depth of caudal peduncle 1.4–1.8 times in its length.
..... 5

5a – ½7–8½ scale rows on caudal peduncle; 36–41 + 2 scales in midlateral row (eastern Greece).
..... *P. marathonicus*

5b – ½8–9½ (mode ½9½) scale rows on caudal peduncle; 38–43 + 1–3 scales in midlateral row.
..... 6

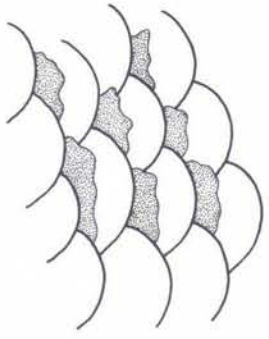

Figure 45 Scales partly covered by scale pockets in *Pelasgus* species (after Kottelat & Barbieri, 2004).

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Pelasgus epiroticus; Lake Pamvotis, Greece; 61 mm SL.

6a – Body ovoid in section; scale pockets exposed in anterior half of body; depth of caudal peduncle 11–13 % SL; in both sexes, belly rounded, ventral profile from pelvic to caudal base clearly concave (Peloponnese, western Greece).
..... *P. stymphalicus*

6b – Body compressed; scale pockets not or only very weakly exposed; depth of caudal peduncle 12–16 % SL; ventral profile from pelvic to caudal base almost straight in male, concave in female (northwestern Greece).
..... *P. thesproticus*

Pelasgus epiroticus

Common name. Tsima.

Diagnosis. Distinguished from other species of *Pelasgus* by: ● 53–58 + 2 scales in midlateral row / ● lateral line incomplete, with 16–23 pored scales / ○ snout short but pointed. Size up to about 100 mm SL.

Distribution. Greece: Lake Pamvotis.

Habitat. Lake shores, among vegetation.

Biology. No data.

Conservation status. CR A2be; B1ab(v). Population has dramatically crashed in the last few years, probably due to habitat changes, overfishing, predation by cormorants. Males density seems very low.

Further reading. Steindachner, 1896: 185 (description); Karaman, 1972: 137 (description); Stephanidis, 1974b: 244 (description); Perdikaris et al., 2003 (status); Kottelat & Barbieri, 2004 (systematics).

Pelasgus laconicus

Common name. Evrotas minnow.

Diagnosis. Distinguished from other species of *Pelasgus* by: ○ 44–48 + 1–2 scales in midlateral row / ○ lateral line absent or incomplete, with 0–8 pored scales / ○ ½10½ scale rows on caudal peduncle / ○ 6–6½ branched anal rays / ● scale pocket exposed on all scales, most developed in anterior half of body where they cover about half of exposed scale area. Size up to 60 mm SL.

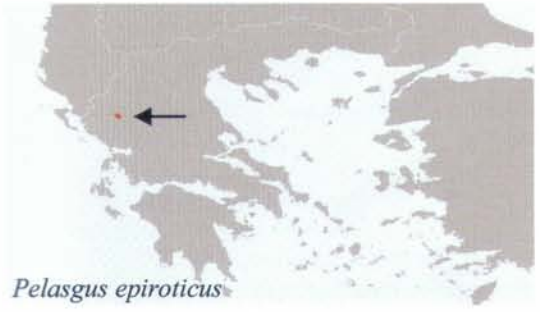
Distribution. Greece: Evrotas and upper Alfios drainages (Peloponnese).

Habitat. Pools, slow-flowing streams, swamps, springs; usually among vegetation or under shore cover.

Biology. Feeds on diatoms, algae, small crustaceans, insects.

Conservation status. CR B2ab(ii,iii,iv,v).

Further reading. Kottelat & Barbieri, 2004: 148 (description).



Pelasgus epiroticus

Pelasgus laconicus

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Pelasgus laconicus; Evrotas, Greece; male, 42 mm SL.

Pelasgus marathonicus; Kifissos drainage, Greece; female, 53 mm SL.

Pelasgus marathonicus

Common name. Marathon minnow.

Diagnosis. Distinguished from other species of *Pelasgus* by: ♂ 36–41 + 2 scales in midlateral row / ♂ lateral line incomplete, with 0–7 pored scales / ♂ ½7–8½ scale rows on caudal peduncle / ♂ 7–7½ branched anal rays. Size up to about 65 mm SL.

Distribution. Greece: Marathon plain and Sperchios and Kifissos drainages.

Habitat. Springs, swamps, canals; usually among vegetation or under shore cover.

Biology. Lives up to 2 years. Spawns in May – September. Feeds on a wide variety of aquatic invertebrates, algae and detritus.

Conservation status. NT.

Further reading. Zardoya & Doadrio, 1999 (genetics); Daoulas et al., 2001: 266 (biology); Kottelat & Barbieri, 2004 (diagnosis).

Pelasgus minutus

Common name. Ohrid minnow.

Diagnosis. Distinguished from other species of *Pelasgus* by: ♂ 42–44 + 2 scales in midlateral row / ♂ lateral line incomplete, with 0–16 pored scales / ♂ depth of caudal peduncle about 1.8–

Pelasgus marathonicus

Pelasgus minutus

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Pelasgus minutus; Morinjska, Montenegro; male, ~40 mm SL.

Pelasgus prespensis; Lake Prespa, Greece; male, 46 mm SL.

2.0 times in its length / ○ 7½ branched anal rays. Size up to about 50 mm SL.

Distribution. Lakes Ohrid and Skadar basins (Albania, Macedonia, Montenegro); Morinjska drainage in Montenegro.

Habitat. Shallow still waters; brooks.

Biology. Reported to live up to 6 years and to spawn for the first time at 3 years, but this seems unlikely; probably matures at 1 year. Spawns in June – July in Lake Ohrid basin. Eggs are deposited among algae or on stones.

Conservation status. DD. Abundant in Skadar, possibly extirpated in Ohrid.

Remarks. The available information is insufficient to distinguish the populations from Lake Ohrid and Montenegro; therefore *P. montenigrinus* is treated as a synonym.

Further reading. Karaman, 1924: 63 (description); Karaman, 1972: 130, 131 (diagnosis; as *Phoxinellus stymphalicus montenigrinus*); Šorić, 1999 (description, biology).

Pelasgus prespensis

Common name. Prespa minnow.

Diagnosis. Distinguished from other species of *Pelasgus* by: ● scales very small, not overlapping, deeply embedded in skin / ● 58–73 + 2 scales in midlateral row / ○ 0–7 lateral line pores. Size up to about 55 mm SL.

Distribution. Lakes Prespa (Greece, Macedonia, Albania).

Habitat. Still waters of lakes and lake shores, with abundant aquatic vegetation.

Biology. In males, anterior pectoral rays stiff and thickened. Probably has an extended spawning season.

Conservation status. EN B1ab(iii,iv,v) + 2ab(iii, iv,v); population declined in recent years, apparently threatened by introduced species (*Pseudorasbora parva*, *Rhodeus amarus*).

Pelasgus prespensis

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Pelasgus stymphalicus; Lake Stymphalia, Greece; male, 34 mm SL.

Pelasgus thesproticus; Acheron drainage, Greece; male, 59 mm SL.

Further reading. Karaman, 1924: 61 (description); Karaman, 1972: 137 (description); Kottelat & Barbieri, 2004 (systematics).

Pelasgus stymphalicus

Common name. Stymphalia minnow.

Diagnosis. Distinguished from other species of *Pelasgus* by: ♦ 40–43 + 1–2 scales in midlateral row / ♦ lateral line absent or incomplete, with 0–14 pored scales / ♦ ½8–9½ scale rows on caudal peduncle / ♦ 7–7½ branched anal rays / ♦ scale pocket exposed only between scales on anterior half of flank / ♦ body with ovoid section / ♦ ventral profile from pelvic to caudal base clearly concave in both sexes / ♦ in females, eye usually closer to dorsal profile. Size up to about 60 mm SL.

Distribution. Greece: Lake Stymphalia (Peloponnese). Populations from lower Alfios and Pinios (Peloponnese), Etolia-Acarnania and Lefkas island treated as conspecific, but this requires further studies.

Habitat. In lakes: littoral pools and marshes, shel-

Pelasgus stymphalicus

Pelasgus thesproticus

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Pelecus cultratus; Danube, Slovakia; ~230 mm SL.

tered bays, and estuaries; slow-flowing stretches of streams, backwaters, springs.
Biology. Lives up to 3 years. Spawns for the first time at 1 year. Spawns repeatedly on vegetation in December – April. In breeding season, males have tubercles on head, chin, upper and lower jaws, and body. Eggs adhesive, 1.1–1.6 mm in diameter, deposited on plants, hatch in 5–7 days. Feeds on diatoms, algae, small crustaceans, insects (in lakes, also on larvae of the mussel *Dreissena polymorpha*).
Conservation status. LC. Adapted to occupy unstable habitats and to quickly re-establish depleted populations. Some populations have declined sharply.
Further reading. Stephanidis, 1971a: 184 (description); Economou et al., 1994a: 24 (larvae); Daoulas et al., 1995 (larvae); Zardoya & Doadrio, 1999 (genetics); Barbieri et al., 2002a: 61 (biology); Kottelat & Barbieri, 2004 (systematics).

Pelasgus thesproticus

Common name. Epiros minnow.
Diagnosis. Distinguished from other species of *Pelasgus* by: ● body compressed, not with ovoid section / ○ 38–43 + 2–3 scales in midlateral row / ○ lateral line incomplete, with 7–14 pored scales / ○ ½8–9½ scale rows on caudal peduncle / ○ 7½ branched anal rays / ○ scale pockets not exposed or only very weakly developed / ○ ventral profile from pelvic to caudal base almost straight in males, concave in females / ○ in females, eye usually at equal distance from dorsal and ventral profiles of head. Size up to 60 mm SL.
Distribution. Greece: from Kalamas to Arachthos drainages, Corfu Island; Albania: Butrint drainage.
Habitat. Springs, streams, ponds, usually in shallow, quiet water with dense vegetation.
Biology. No data.
Conservation status. NT. Threatened by land reclamation and water abstraction.
Further reading. Stephanidis, 1939a: 24 (description); Zardoya & Doadrio, 1999 (genetics); Kottelat & Barbieri, 2004 (diagnosis).

Pelecus cultratus

Common name. Razor fish.
Diagnosis. Only species of genus. Distinguished from other species of Cyprinidae in Europe by: ● lateral line running in an undulated line / ○ 24–29½ branched anal rays / ○ mouth superior / ○ body very elongate and compressed / ● dorsal profile almost straight / ○ sharp, scaleless keel from throat to anus / ● dorsal base entirely above anal base. Size up to 500 mm SL.
Distribution. Black, Caspian and Aral Sea basins; Baltic basin from Vistula to Neva drainages, southern Sweden and Finland, Lakes Ladoga and Onega. Occasionally on Baltic coast west of Vistula and on Finnish coast north of 61°N.
Habitat. Surface of open waters of large rivers and lakes. Abundant in reservoirs (Don, Volga). Semi-anadromous individuals forage and spawn in pelagic zone of freshened parts of sea or lower parts of rivers, in main channel or floodplains. Lacustrine populations spawn in open water of lakes.
Biology. Lives up to 9 years. Spawns for the first time at 3–5 years, 200–300 mm SL. Semi-anadromous individuals start entering rivers in July (Don). When rivers are covered by ice, spawning migration ceases and is resumed with breaking up of ice in April – May. Resident individuals are found in rivers year-round. Spawns in May – June, earlier in southern drainages (April in Syr-Darya) at temperatures above 12°C. Eggs are semi-pelagic and drift with the current (in rivers). Eggs hatch

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Petroleuciscus borysthenicus; Sochi, Russia; ~90 mm SL.

after 3–4 days. Adults return to estuaries to forage immediately after spawning. Juveniles may migrate to estuaries during first summer. Feeds on zooplankton, terrestrial invertebrates and small fish.

Conservation status. LC. Semi-anadromous populations markedly declined in Black Sea basin following impoundment of rivers. They have stabilised since.

Remarks. The relationships of this species are not yet clear. It is unique among European cyprinids with is long, slender, highly compressed body with a sharp keel from throat to anus, but this appearance is shared with some Asian species, especially *Macrochirichthys macrochirus*. In recent years it has been placed in the Leuciscinae or the Cultrinae. We tentatively place it in Leuciscinae.

Further reading. Berg, 1949 (biology); Balon, 1956 (biology); Bogutskaya, 1988b (osteology).

Petroleuciscus

The genus *Petroleuciscus* includes 6 species earlier placed in *Leuciscus*. They occur from the Black Sea and eastern Aegean drainages, eastward to Iran and Uzbekistan. One species is known from continental Europe and one from the Greek island of Lesbos, along the coast of Turkey.

Petroleuciscus borysthenicus

Common name. Bobyretz chub.

Diagnosis. Only species of genus in continental Europe. Distinguished from *P. smyrnaeus* by: ● 8–9½ branched dorsal rays / ● 9–10½ branched anal rays / ● iris orange to red / ○ 33–40 total lateral line scales / ○ posterior margin of anal convex or almost straight / ● no black pigments along free margin of each flank scale. Size up to 185 mm SL, females usually up to 110 mm SL, males up to 80 mm.

Distribution. Western, northern and eastern Black Sea and Sea of Azov basins, from Bulgaria clockwise to Kızılırmak drainage in northern-central Turkey (missing in Don); Aegean Sea basin, from Struma drainage eastward in Europe; northwestern Turkey. In lower reaches of rivers and coastal lakes, but in Dniepr up to Seim and Desna systems.

Habitat. Lowland rivers, lower reaches of montane rivers, limans, lakes, deltas, backwaters with moderate to no current. Prefers warm water with temperatures up to 30–32°C. Quite resistant to low oxygen concentrations, sometimes in marshes and water bodies with dense vegetation. Tolerant of slightly brackish waters. Prefers sand, sand-mud or mud bottom. Prefers shallow places with slow current along banks, in backwaters, in small lakes and similar calm-water sites.

Biology. Lives up to 8 years. Spawns for the first time at 2–3 years, males may spawn at 1 year. Forms spawning groups of up to 150 individuals. Spawns in April – June at 12–28°C, in 0.1–1.0 m deep water, over sandy or slightly muddy bottom. Females lay 2–3 portions of adhesive eggs on and amidst aquatic plants each spawning period. Usually stays in groups of 5–30 individuals in vegetation at bottom but sometimes near water surface, under floating leaves or other objects. Does not migrate but moves in winter to deeper places. Feeds mainly on insects and their larvae, also plankton, benthic invertebrates and algae.

Conservation status. LC. Some populations are declining sharply due to drainage of flood-plains

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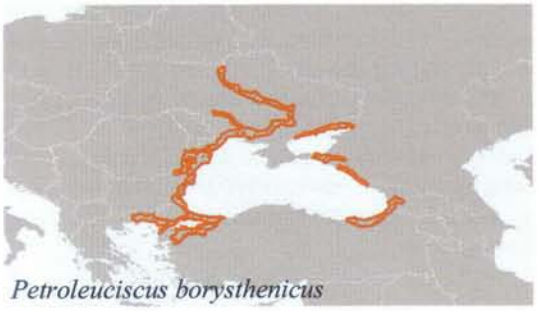
Petroleuciscus smyrnaeus; Lesbos Island, Greece; 100 mm SL.

Petroleuciscus smyrnaeus; Bergama, Turkey; 72 mm SL.

and channelization of river beds.
Further reading. Movchan & Smirnov, 1981 (description, biology); Bogutskaya, 1996: 26 (taxonomy), 2002 (systematics).

Petroleuciscus smyrnaeus

Common name. Smyrna chub.
Diagnosis. Only species of genus in Lesbos Island and southwestern Turkey. Distinguished from *P. borysthenicus* by: ● 7½ branched dorsal rays / ● usually 8½ branched anal rays / ● iris whitish / ○ 32–35 total lateral line scales / ○ posterior margin of anal straight or slightly concave / ● black pigments along free margin of each flank scale. Size up to at least 100 mm SL.
Distribution. Lesbos Island (Greece) and Aegean drainages of southwestern Turkey, from Izmir to Güllück.
Habitat. Slow-flowing to standing water.
Biology. No data.
Conservation status. DD. In Lesbos, two known localities, heavily impacted by human activities.
Further reading. Bogutskaya, 1996: 34 (description), 2002 (systematics); Stoumboudi et al., 2006: 132 (Lesbos population).



Petroleuciscus borysthenicus

Petroleuciscus smyrnaeus

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Phoxinellus alepidotus; Korona, Bosnia-Herzegovina; ~55 mm SL.

Phoxinellus

Species of *Phoxinellus* are characterised by their reduced squamation. In all species, scales are lacking on part of the body, one species is almost naked, retaining only the pored lateral line scales. (For these species, the number of lateral line scales refers to the number of pored scales; these numbers can be very variable in some species, reflecting the variability in scale development.)

All *Phoxinellus* have restricted distribution ranges. All are known from a single or a few karstic basins in Croatia and Bosnia-Herzegovina. Some of these basins may dry during the summer and the fish survive in springs and caves. As previously accepted, the genus was polyphyletic and some of the species earlier referred to *Phoxinellus* have recently been transferred to *Delminichthys* and *Telestes*.

Keys to species of *Phoxinellus*

1a – Mouth terminal; caudal shallowly forked. ..... *P. dalmaticus*

1b – Mouth subterminal; caudal moderately forked. 2

2a – Lateral line usually with 11–42 pored scales, ending from above pelvic to anal origin. ..... *P. alepidotus*

2b – Lateral line usually with 54–77 pored scales, ending on caudal peduncle. ..... *P. pseudalepidotus*

Phoxinellus alepidotus

Common name. Naked minnow.

Diagnosis. Distinguished from other species of *Phoxinellus* by: ● naked body, no scales except for lateral line scales / ○ lateral line usually with 11–42 pored scales, ending between pelvic origin and anal origin / ○ caudal moderately forked / ○ mouth subterminal. Size up to 145 mm SL.

Distribution. Streams in Glamočko, Livanjsko poljes. Also reported from Duvanjsko ploje, Lakes Buško and Blidinje and intermittent streams Korana and Struga near Bosansko Grahovo (Bosnia-Herzegovina).

Habitat. Streams with clear water. Enters subterranean karstic waters during winter or droughts.

Biology. Females spawn for the first time at about 46 mm SL, males at about 43 mm SL. Spawns in April – June in shallower parts of streams. Females probably lay 2–3 portions of eggs.

Conservation status. EN B2ab(ii,iii,iv). Threatened by pollution, habitat destruction and introduction of exotic species. Limited data suggest decline during last 10 years, which is likely to continue because of water abstraction and introductions.

Further reading. Zupančič & Bogutskaya, 2000: 76 (systematics); Marić, 1990 (reproduction, cave population); Bogutskaya & Zupančič, 2003 (morphology).

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Phoxinellus dalmaticus; Vrba, Krka drainage, Croatia; ~60 mm SL.

Phoxinellus pseudalepidotus; Mostarsko Blato, Bosnia-Herzegovina; ~60 mm SL.

Phoxinellus dalmaticus

Common name. Čikola minnow.

Diagnosis. Distinguished from other species of *Phoxinellus* by: ● mouth terminal / ○ body scaleless, except for midlateral row and a few scales above lateral line behind head / ○ 18–45 total scales in midlateral row, lateral line often interrupted posteriorly, with 16–29 pored scales, ending between pelvic base and almost end of caudal peduncle / ● shallowly forked caudal, with rounded lobes. Size up to at least 60 mm SL.

Distribution. Croatia: stream Čikola in Krka drainage.

Habitat. Streams with slow current.

Biology. Spawns in June. Ripe males have conical nuptial tubercles on first pectoral ray, along two longest anal rays, on most lateral line scales and on head.

Conservation status. CR B1ab(ii) + 2ab(ii), threatened by water abstraction and pollution.

Further reading. Zupančič & Bogutskaya, 2000: 70 (systematics, habitat, biology).

Phoxinellus pseudalepidotus

Common name. Mostar minnow.

Diagnosis. Distinguished from other species of *Phoxinellus* by: ○ body scaleless, except for lateral line scales and some scales above and below lateral line behind head / ● lateral line usually with 54–77 total scales, ending on caudal peduncle posterior to anal base / ○ caudal moderately forked / ○ mouth subterminal. Size up to 100 mm SL.

Phoxinellus alepidotus

Phoxinellus dalmaticus

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Distribution. Streams and lakes in Mostarsko Blato, Neretva drainage (Bosnia-Herzegovina).
Habitat. Shallow channels with slow current and clean water.
Biology. Spawns for the first time at about 48–52 mm SL. Spawns in May, probably also later. Females probably lay several portions of eggs.
Conservation status. VU D2.
Further reading. Bogutskaya & Zupančič, 2003: 371 (description).

Phoxinellus pseudalepidotus

Phoxinus

Species of *Phoxinus* are characterised by their numerous small scales, the lateral line often incomplete and a colour pattern of a midlateral row of squarish to vertically elongated blotches, often fused into a midlateral stripe, especially in juveniles. The colour pattern changes in the spawning season, especially in males, which may develop a pattern of elongated blotches on side, a blackish lower half of flank or a copper-goldish hue on whole body. Sexually active males have conspicuous tubercles on top of head and the opercle has a swollen, bright white margin. The diagnoses and key do not include these temporary characters as they have not yet been reported for all species. In most species, the belly is naked between the pectorals, but there is a patch of scales between the base of each pectoral and the gill opening. These 'breast scales' are margined by small tubercles in the breeding season and they are organised in patches whose shape is useful to diagnose species (Fig. 46).

The genus is distributed throughout Europe and northern Asia. Several North American species have been placed in *Phoxinus* but molecular data suggest that they are not congeneric. At some time, all European *Phoxinus* were identified as *P. phoxinus*, despite considerable morphological diversity. We recognize seven species in European waters. More work is needed on the taxonomy of the southeastern European populations. Other European species earlier placed in *Phoxinus*, *Morocco* or *Eupallasella* belong to the genus *Rhynchocypris*.
Further reading. Chen, 1996 (morphology); Howes, 1985 (morphology); Sakai et al., 2006 (phylogeny); Kottelat, 2007a (systematics).

Key to species of *Phoxinus* in Europe

1a – Scales on belly between pectoral bases; a supraorbital ridge margined by a longitudinal depression extending from the nostrils backwards (Caucasus). ..... *P. colchicus*

1b – No scales on belly between pectoral bases, or present only in a small number or exceptional individuals in each population; no supraorbital ridge, no depression behind nostrils. 2

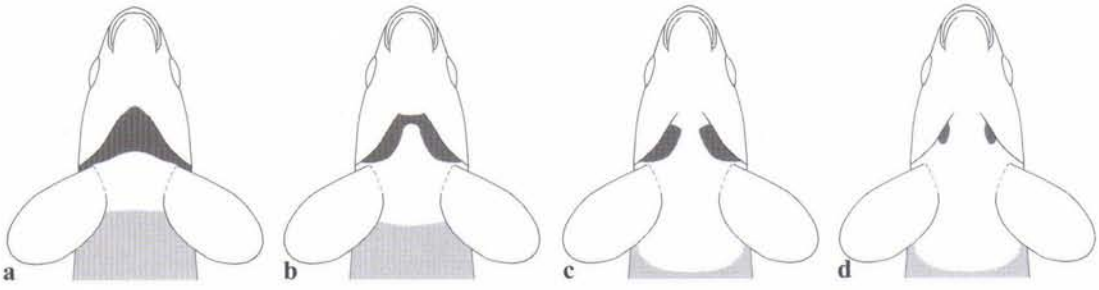

Figure 46 Patches of breast scales in *Phoxinus* species; **a,** continuous across breast; **b,** connected anteriorly; **c,** separated by unscaled area; **d,** missing or restricted to very few scales. Dark grey: patches of breast scales; pale grey: normal scales (after Kottelat, 2007).

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2a – Patches of breast scales continuous across breast (Fig. 46a); depth of caudal peduncle 2.1–2.9 times in its length (southern France).
..... *P. septimaniae*

2b – Patches of breast scales absent, separated by unscaled area (Fig. 46c) or connected only anteriorly (Fig. 46b); if connected anteriorly, then depth of caudal peduncle 2.5–3.3 times in its length).
..... 3

3a – Anal origin below or behind base of last dorsal ray; margin of anal straight to convex.
..... 4

3b – Anal origin usually in front of base of last dorsal ray; margin of anal concave to straight.
..... 5

4a – In adults, length of anal about equal to length of caudal peduncle; distance between tip of of first and last branched anal rays 1.1–1.8 times depth of caudal peduncle (with fin stretched out); interorbital width 33–43 % HL; dorsal profile of head almost horizontal above eye, then abruptly descending towards tip of snout; marked hump at nape in largest individuals (Adour and Ebro drainages).
..... *P. bigerri*

4b – In adults, length of anal about ¾ of length of caudal peduncle; distance between tip of of first and last branched anal rays 0.8–1.2 times depth of caudal peduncle (with fin stretched out); interorbital width 30–35 % HL; dorsal profile of head regularly descending towards tip of snout; no hump at nape (Resowska and Veleka drainages).
..... *P. strandjae*

5a – Dorsal profile of head conspicuously more convex than ventral profile; patches of breast scales missing or restricted to a few scales (Fig. 46d) (Strymon drainage).
..... *P. strymonicus*

5b – Dorsal profile of head about as convex as ventral profile; a scale patch in front of each pectoral base (Fig. 46c).
..... 6

6a – Flank with a faint midlateral stripe, more or less dissociated into squarish blotches; dorsal half of body goldish-bronze with few darker vermiculations; lateral line usually incomplete, ending between pelvic origin and anal base; snout length 26–29 % HL, 0.9–1.2 times eye diameter (Adriatic drainages).
..... *P. lumaireul*

5b – Flank with a midlateral row of vertically elongated blotches whose depth is about ⅓–½ of body depth at same position; dorsal half of body greenish brown with numerous blackish vermiculations; lateral line usually reaching beyond anal base; snout length 29–34 % HL, 1.1–1.4 times eye diameter.
..... *P. phoxinus*

Phoxinus bigerri

Common name. Adour minnow.

Diagnosis. Distinguished from other species of *Phoxinus* in Europe by: ○ anal origin below or behind base of last dorsal ray / ○ in adults, length of anal about equal to length of caudal peduncle / ○ margin of anal straight to convex / ● distance between tip of first and last branched anal rays 1.1–1.8 times depth of caudal peduncle (with fin stretched out) / ● dorsal profile of head almost horizontal above eye, then abruptly descending towards tip of snout / ○ patches of breast scales separated by unscaled area (Fig. 46c) or connected anteriorly by 1–2 rows of scales (Fig. 46b) / ○ lateral line usually reaching almost to end of caudal peduncle / ○ in preserved individuals, flank with a midlateral row of vertically elongated blotches whose depth is about ⅓–½ of body depth at same position / ○ depth of caudal peduncle 2.2–3.1 times in its length / ○ interorbital width 33–43 % HL / ○ marked hump at nape in largest individuals. Size up to at least 66 mm SL.

Distribution. France: Adour drainage. Spain: Ebro drainage and streams of Cantabric range (possibly introduced in some). Introduced into Douro drainage.

Habitat. Streams and creeks in foothills with clear and cold water, and gravel to stone bottom.

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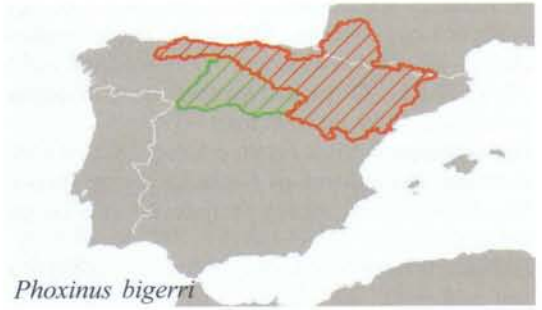
Phoxinus bigerri; Adour, France; 61 mm SL.

Phoxinus colchicus; Sochi, Russia; ~75 mm SL. S. Tuniev

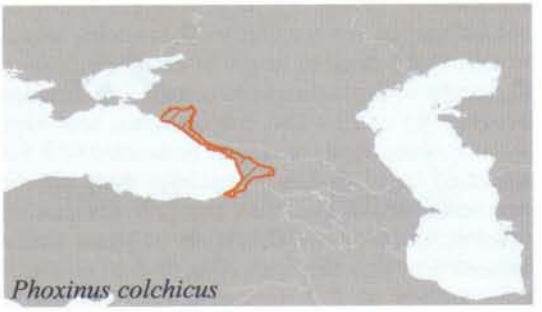
Biology. Gregarious. Spawns in April – June. Feeds mainly on aquatic invertebrates.
Conservation status. LC.
Remarks. Identification of the Iberian populations is tentative.
Further reading. Doadrio, 2001: 193 (biology); Kottelat, 2007a: 146 (description).

Phoxinus colchicus

Common name. Caucasian minnow.
Diagnosis. Distinguished from other species of *Phoxinus* in Europe by: O in preserved individuals, dark bars on body extending on almost entire body depth / ● belly between pectoral bases entirely covered by scales / ● a supraorbital ridge margined by a longitudinal depression extending from nostrils backwards / O depth of caudal peduncle 2.1–2.5 times in its length. Size up to 82 mm SL.
Distribution. In Europe: southern tributaries of lower Kuban. Caucasian Black Sea basin of Russia, Georgia. Historical record from Hopa (eastern Turkey) not confirmed in recent years.
Habitat. A wide range of cold and well oxygenated habitats from small, fast-flowing streams to large rivers. Associated with salmonid fishes or cyprinids of barbel zone. Spawns over clean gravel areas in flowing water.
Biology. Gregarious, rheophilic. Spawns in April – July. Spawns in shoals, fractional spawner, females deposit the sticky eggs deep into clean gravel. Feeds on invertebrates, algae and detritus.
Conservation status. LC.
Remarks. May include two species.



Phoxinus bigerri



Phoxinus colchicus

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Phoxinus colchicus; Sochi, Russia; 72 mm SL.

Phoxinus lumaireul; Zrmanja drainage, Croatia; ~50 mm SL.

Further reading. Berg, 1949: 591 (description); Kottelat, 2007a: 156 (systematics).

Phoxinus lumaireul

Common name. Italian minnow.

Diagnosis. Distinguished from other species of *Phoxinus* in Europe by: ❍ lateral line usually incomplete, ending between pelvic origin and anal base / ❍ in preserved individuals, flank with a faint midlateral stripe, more or less dissociated into squarish blotches, dorsal half of body goldish-bronze with few darker vermiculations / ❍ patches of breast scales separated by unscaled area (Fig. 46c) / ❍ depth of caudal peduncle 2.2–2.6 times in it length / ❍ snout length 26–29 % HL, 0.9–1.1 times eye diameter / ❍ anal origin usually in front of base of last dorsal ray. Size up to about 80 mm SL.

Distribution. Adriatic basin, from Po to Drin drainages. Introduced elsewhere in Italy.

Habitat. Small streams with clear, cold, well oxygenated water, over gravel to stone bottom. Most common in foot hills. In plains, usually associated with springs.

Biology. Gregarious. Lives up to 6 years, usually 3 years. Spawns for the first time at 2 years in hilly areas, sometimes at 1 year in lowland. Spawns in May – July, in groups of one or a few females and numerous males. Eggs are desposited in shallow water on sand or gravel bottom. Fractional spawner. Eggs hatch in 4–5 days at 18°C. Feeds on aquatic macroinvertebrates and algae.

Conservation status. LC.

Remarks. The identity of the populations from Drin and Skadar drainages requires investigation.

Further reading. Gandolfi et al., 1991: 155 (biology); Kottelat, 2007a: 156 (systematics).

Phoxinus phoxinus

Common name. Minnow.

Diagnosis. Distinguished from other species of *Phoxinus* in Europe by: ❍ lateral line usually reaching beyond anal base / ❍ in preserved individuals, flank with a midlateral row of vertically elongated blotches whose depth is about ⅓–½ of body depth at same position, often fused in a midlateral stripe / ❍ depth of caudal peduncle 2.6–3.1 times in its length / ❍ patches of breast scales

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Phoxinus phoxinus; Doubs, Rhône drainage, Switzerland; 64 mm SL.

Phoxinus phoxinus; Danube drainage, Germany; ~80 mm SL. A. Hartl

separated by unscaled area (Fig. 46c) or (rarely) connected anteriorly by 1–2 rows of scales (Fig. 46b) / O snout length 29–34 % HL, 1.1–1.4 times eye diameter / O anal origin in front of base of last dorsal ray. Size up to 100 mm SL.

Distribution. Basins of Atlantic, North and Baltic Seas, Arctic and northern Pacific Ocean, from Garonne (France) eastward to Anadyr and Amur drainages and Korea; Ireland (possibly introduced), Great Britain northward to 58°N, Scandinavia and Russia northernmost extremity, Rhône drainage. Recorded from upper and middle Volga and Ural drainages, Lake Balkhash (Kazakhstan) and upper Syr-Darya drainage (Aral basin), but these identifications require confirmation. Introduced elsewhere.

Habitat. A wide range of cold and well oxygenated habitats from small, fast-flowing streams to large Nordic lowland rivers and from small upland lakes to large oligotrophic lakes. Usually associated with salmonid fishes. Spawning takes place over clean gravel areas in flowing water or on wave-washed shores of lakes. Overwinters in coarse substrate or in deep pools with low current.

Biology. Gregarious, rheophilous. Lives up to 11 years, usually up to 4–5 years. Spawns for the first time at 2 years. Spawns in April – June at temperatures above 10°C. Some individuals spawn even during autumn. Males and females school separately and arrive on spawning sites at different times. Fractional spawner, females deposit the sticky eggs deep into clean gravel. Feeds on invertebrates, algae and detritus.

Conservation status. LC. Locally threatened by pollution and excessive stocking of species of *Salmo*.

Remarks. The systematics of *Phoxinus* is far from

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Phoxinus septimaniae; Agly, France; 53 mm SL.

Phoxinus septimaniae; Hérault drainage, France; 46 mm SL.

resolved and our observations suggest that several species are confused under the name *P. phoxinus*.
Further reading. Tack, 1941 (biology); Repa, 1976 (morphometry); Repa & Pivnička, 1980 (morphometry); Bless, 1992 (ecology); Kottelat, 2007a: 155 (systematics).

Phoxinus septimaniae

Common name. Languedoc minnow.
Diagnosis. Distinguished from other species of *Phoxinus* in Europe by: ● patches of breast scales continuous across breast (Fig. 46a) / ○ lateral line usually reaching at least anal base / ○ in preserved individuals, flank with a faint midlateral stripe, more or less dissociated into squarish blotches, dorsal half of body goldish-bronze with few darker vermiculations / ○ depth of caudal peduncle 2.1–2.9 times in it length / ○ snout length 28–33 % HL, 0.9–1.3 times eye diameter / ○ anal origin below or behind base of last dorsal ray. Size up to about 65 mm SL.
Distribution. France: Mediterranean coastal streams from Gardon to Tech; probably extends further to south and east. Possibly an introgression zone with *P. phoxinus* in lower Rhône, from about Lyon southward.
Habitat. Small streams with clear, cold, well oxygenated water, over gravel to stone bottom.
Biology. No data.
Conservation status. LC.
Further reading. Kottelat, 2007a: 148 (description).

Phoxinus strandjae

Common name. Strandzha minnow.
Diagnosis. Distinguished from other species of *Phoxinus* in Europe by: ○ anal origin below or behind base of last dorsal ray / ○ in adults, length of anal fin about ¾ of length of caudal peduncle / ○ margin of anal straight to slightly convex / ○ distance between tip of first and last branched anal rays 0.8–1.2 times depth of caudal peduncle (with fin stretched out) / ○ patches of breast scales connected anteriorly across the throat (Fig. 46b) / ○ lateral line reaching almost to end of caudal peduncle / ○ in preserved individuals, flank with a midlateral row of vertically elongated blotches whose depth is about ⅓–½ of body depth at same

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Phoxinus strandjae; Resowska, Turkey; ~50 mm SL. M. Özuluğ

Phoxinus strymonicus; Struma drainage, Greece; 37 mm SL.

position / ○ depth of caudal peduncle 2.5–2.8 times in its length / ○ interorbital width 30–35 % HL. Size up to at least 67 mm SL.

Distribution. Veleka and Resowska drainages, draining from Strandzha (Yıldız Dagları) range to Black Sea (Bulgaria, Turkey).

Habitat. Small streams with clear, well oxygenated water, over gravel to stone bottom.

Biology. No data.

Conservation status. EN B1ab(ii,iii).

Further reading. Kottelat, 2007a: 156 (diagnosis).

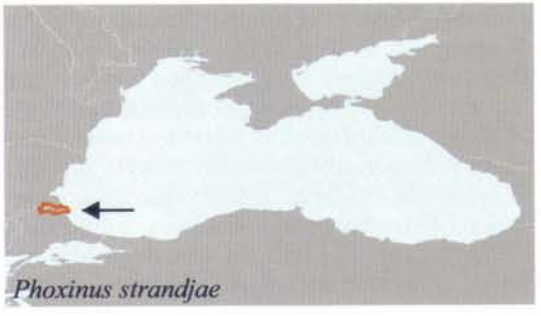
Phoxinus strymonicus

Common name. Aegean minnow.

Diagnosis. Distinguished from other species of *Phoxinus* in Europe by: ● no breast scales or only small patches (Fig. 46d) / ○ depth of caudal peduncle 2.1–2.5 times in its length / ○ head length 27–29 % SL / ○ predorsal length 56–60 % SL / ○ pre-anal length 62–68 % SL / ○ anal origin usually in front of base of last dorsal ray. Size up to 48 mm SL.

Distribution. Aegean Sea basin, Struma drainage (Greece, probably Bulgaria); *Phoxinus* populations in Loudias and Filiouris drainages (Greece) are possibly conspecific.

Habitat. Most abundant in small streams with clear



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Pimephales promelas; Wisconsin, U.S.A.; 53 mm SL. D. Neely

Protochondrostoma genei; Ombrone drainage, Italy; ~140 mm SL.

and cold water; also found in irrigation canals.
Biology. No data.
Conservation status. EN B1ab(iii).
Further reading. Kottelat, 2007a: 151 (description).

Pimephales promelas

Common name. Fathead minnow.
Diagnosis. Only species of genus introduced to Europe. Distinguished from other species of Cyprinidae in Europe by: ● male with prominent pad of spongy tissue on nape / ○ dorsal origin about above pelvic origin / ○ 7½ branched anal rays / ○ second simple dorsal ray spinous, about 50 % length of third one / ○ lateral line incomplete, usually not reaching dorsal origin / ○ weak midlateral stripe / ○ 41–54 + 2 scales in midlateral row / ○ mouth terminal. Size up to 50 mm SL.
Distribution. Native to North America in Mississippi, St. Lawrence and MacKenzie drainages and Hudson Bay basin, widely introduced within and outside its native range. Locally introduced in France and Belgium.
Habitat. Lakes, pools and backwaters in warm water habitats. Spawns in still-water habitats along shores.
Biology. Spawns for the first time at 1–2 year, some even reproduce in late summer of their first year. Spawns in May – August when temperature rises above 15°C. Males defend territories and eggs, and clean plants, stones or other materials by rubbing them with the spongy nape pad and dorsal fin, which contain mucus-secreting cells and taste buds. The mucus may have fungicidal properties. One to several females lay a single layer of eggs on the prepared surfaces. Females are fractional spawners, spawning every 2–26 days. Seems to be a weak competitor; usually abundant only in low diversity fish communities. Omnivorous.
Conservation status. Alien.
Further reading. Jenkins & Burkhead, 1993: 449 (biology).

Protochondrostoma genei

Common name. Lasca.
Diagnosis. Only species in genus. Distinguished

Protochondrostoma genei

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Pseudochondrostoma duriense; Douro drainage, Portugal, ~120 mm SL.

Tributary of River Ombrone, Italy; habitat of *Protochondrostoma genei*, *Squalius lucumonis*, *Barbus tyberinus* and *Rutilus rubilio*.

from species of *Chondrostoma* in Apennine Peninsula by: ● broad dark midlateral stripe from head to caudal base / ● mouth arched, lower lip with thin but well developed cornified sheath / ○ 50–62 total lateral line scales / ● 8½ branched dorsal rays / ● 14–19 gill rakers / ● body slender, depth 20–27 % SL / ○ pectoral, pelvic, anal and caudal at least with red basis. Size up to 200 mm SL.

Distribution. Adriatic basin, from Soca to Vomano drainages (Italy, Slovenia). Introduced to Tuscany and Latium in Centa, Magra, Arno, Ombrone and Tevere basins.

Habitat. Middle reaches of rivers and main tributaries, in piedmont, with moderate to swift current, over gravel bottom. Spawns on gravel, in swift current.

Biology. Gregarious. Large groups undertake small spawning migrations towards main tributaries. Spawns in May – June. Omnivorous; feeds mainly on aquatic insects and epilithic algae.

Remarks. Earlier placed in *Chondrostoma* (see comments under this genus). Might belong to *Parachondrostoma*.

Conservation status. LC. Almost extirpated in River Soca due to invasion by *Chondrostoma nasus*, which seems to be a strong competitor.

Further reading. Elvira, 1987: 119 (diagnosis); Gandolfi et al., 1991: 187 (biology); Bianco, 1995a: 166 (distribution).

Pseudochondrostoma

This genus in endemic to the Iberian Peninsula. The species were earlier placed in *Chondrostoma* (see comments under this genus). The published diagnoses of several species do not efficiently differentiate them and the following key is tentative.

Key to species of *Pseudochondrostoma*

1a – Depth of caudal peduncle 2.2–2.4 times in its length; usually 7–6 (sometimes 6–6) pharyngeal teeth; ½9–10/1/4–5 scales in transverse series between dorsal and pelvic origins; 9–10½ branched anal rays; 26–35 gill rakers (Guadiana, Odiel, Guadalquivir and adjacent smaller drainages).
..... *P. willkommii*

1b – Depth of caudal peduncle 1.9–2.1 times in its length; 6–5 or 5–5 pharyngeal teeth; ½10–12/1/5–6 scales in transverse series between dorsal and pelvic origins; 8–9½ branched anal rays; 18–31 gill rakers.
..... 2

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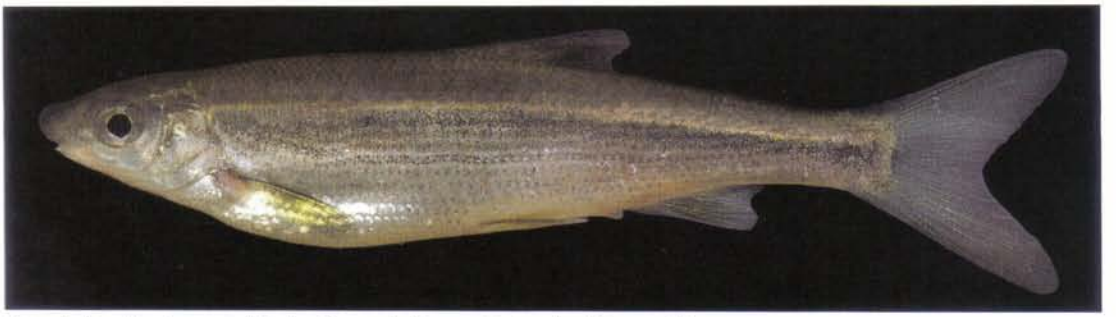


Pseudochondrostoma polylepis; Tagus drainage, Portugal; ~90 mm SL.

2a – Edge of lower jaw slightly arched; 5–5 pharyngeal teeth; usually 8½ branched anal rays; 18–24 gill rakers; individuals from Portugal and Galicia with numerous small black dots on upper half of body (from Douro drainage to Galicia).
..... *P. duriense*

2b – Edge of lower jaw straight; usually 6–5 (sometimes 5–5) pharyngeal teeth; usually 9½ branched anal rays; 19–31 gill rakers; no black spots on body (Tagus and adjacent smaller drainages).
..... *P. polylepis*

Pseudochondrostoma duriense

Common name. Douro nase.

Diagnosis. Distinguished from other species of *Pseudochondrostoma* by: ○ edge of lower jaw slightly arched / ○ 60–70 + 3–4 lateral line scales / ○ usually 8½ branched anal rays / ○ 18–24 gill rakers / ○ 5–5 pharyngeal teeth / ● individuals from Portugal and Galicia with numerous small black dots on upper half of body / ○ depth of caudal peduncle 1.9–2.1 times in its length. Size up to 400 mm SL.

Distribution. Iberian Peninsula, from Douro drainage to Galicia.

Habitat. Middle stretches of rivers, in areas with current.

Biology. Gregarious, especially during the pre-reproduction migration. Spawns in April – June. Feeds on vegetal matter, supplemented by small invertebrates and detritus.

Conservation status. VU A3ce.

Further reading. Coelho, 1985: 33 (description); Doadrio, 2001: 172 (biology).

Pseudochondrostoma polylepis

Common name. Tagus nase.

Diagnosis. Distinguished from other species of *Pseudochondrostoma* by: ○ edge of lower jaw straight / ○ 61–75 + 3–4 lateral line scales / ○ usually 9½ branched anal rays / ○ 22–31 gill rakers / ○ usually 6–5 pharyngeal teeth / ○ depth of caudal peduncle 1.8–2.2 times in its length. Size up to 400 mm SL.

Distribution. Tagus drainage (Spain, Portugal); Vouga, Mondego, Algoa and Sado drainages (Portugal). Introduced in Jucar and Segura drainages (Spain).

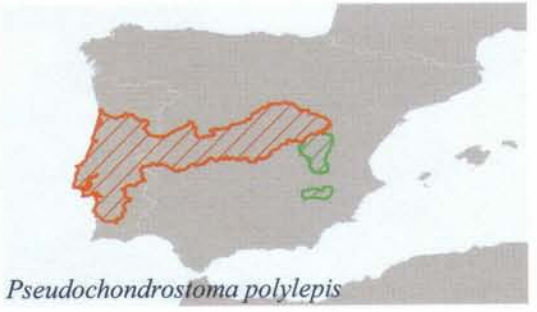
Habitat. Middle stretches of rivers, in areas with current; survives in reservoirs.

Biology. Gregarious, especially during pre-reproduction migration. Spawns for the first time at 3–4 years. Spawns in March – June. Feeds on vegetal matter, supplemented by small invertebrates and detritus.

Conservation status. LC.

Further reading. Coelho, 1985 (systematics); Doadrio, 2001: 179 (biology); Robalo et al., 2003 (behaviour).

Pseudochondrostoma duriense



Pseudochondrostoma polylepis

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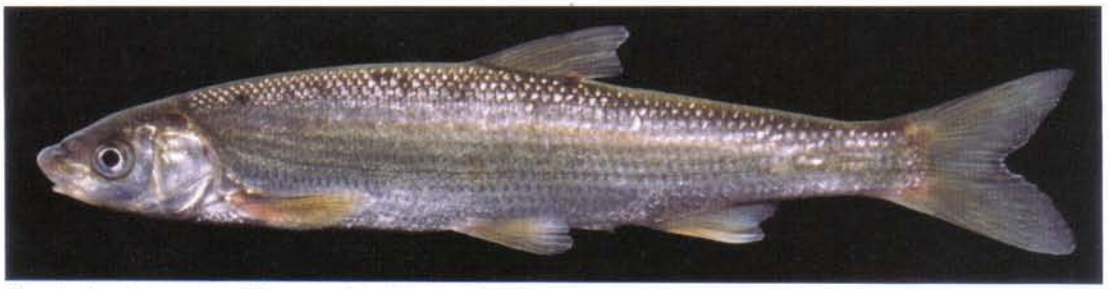

Pseudochondrostoma willkommii; Guadiana drainage, Portugal; ~140 mm SL.

Rhynchocypris czekanowskii; Onon, Amur drainage, Mongolia; 86 mm SL

Pseudochondrostoma willkommii

Common name. Guadiana nase.

Diagnosis. Distinguished from other species of *Pseudochondrostoma* by: ○ edge of lower jaw slightly arched / ○ 56–71 + 3–4 lateral line scales / ○ 9–10½ branched anal rays / ○ 26–35 gill rakers / ○ usually 7–6 pharyngeal teeth / ○ depth of caudal peduncle 2.2–2.4 times in its length. Size up to 400 mm SL.

Distribution. Portugal and Spain, in Guadiana, Odiel, Guadalquivir and smaller drainages, eastward until Malaga.

Habitat. Middle stretches of rivers, in areas with current; frequent in still water.

Biology. Gregarious, especially during pre-reproduction migration. Spawns in April. Feeds on vegetal matter, small invertebrates and detritus.

Conservation status. VU A3ce + 4ce.

Further reading. Coelho, 1985 (systematics; as *Chondrostoma polylepis*); Doadrio, 2001: 184 (biology; as *C. polylepis*).

Rhynchocypris czekanowskii

Common name. Siberian minnow.

Diagnosis. Distinguished from *R. percnurus* by: ● male genital papilla with a long pointed conical projection / ○ body depth smaller than length of caudal peduncle. Size up to 90 mm SL.

Distribution. Arctic Ocean basin, from Kara to Kolyma drainages; Amur drainage (Russia, Mongolia and China).

Habitat. Swamps, backwaters.

Biology. No data.

Conservation status. LC.

Further reading. Berg, 1948: 579 (description); Howes, 1985 (anatomy); Sakai et al., 2006 (phylogeny).

Rhynchocypris percnurus

Common name. Swamp minnow.

Diagnosis. Distinguished from *R. czekanowskii* by: ● male genital papilla not long and pointed / ○ body depth greater than or equal to length of

Pseudochondrostoma willkommii

Rhynchocypris czekanowskii

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Rhynchocypris percnurus; Vistula drainage, Poland; ~70 mm SL.

Rhynchocypris percnurus; Onon, Amur drainage, Mongolia; 47 mm SL.

caudal peduncle. Size up to 185 mm SL, up to 120 mm SL in European populations.

Distribution. Wide but highly disjunct range: lakes in Odra, Vistula, Dniepr, Volga (Oka and Kama systems) drainages, isolated localities in Middle Volga, lakes in Arctic Ocean (from Northern Dvina to Kolyma drainages) and Pacific basins (from Amur to Korea and Japan).

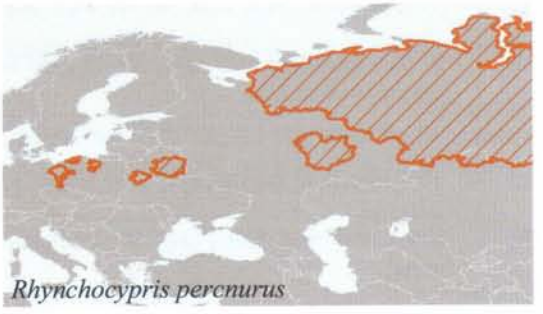
Habitat. Small lakes, shallows or isolated small bays of larger lakes, swamps, artificial ponds, with abundant vegetation, turbid water, with mud or clay bottom. Prefers still water or slow current.

Biology. Spawns for the first time at 2–3 years and usually over 40 mm SL. Spawns in May – July, when temperatures reach 7–9°C. Females lay 3–4 portions of adhesive eggs among underwater plants each season. Embryonic development lasts 10–15 days. Commonly stays in shallows among vegetation in schools of 20–80 individuals. Survives extreme low oxygen concentrations in summer and winter. Spends winter in hibernation (in northern regions) or is inactive at temperatures close to 0°C. Feeds on a wide variety of prey, from plankton to benthic animals.

Conservation status. LC. Globally not threatened, but some isolated relict populations in Middle Volga and Poland have already been extirpated, are declining or threatened. In fact, several of these populations are suspected to be distinct species, which, if confirmed, will significantly modify the present conservation assessment.

Remarks. Earlier called *Phoxinus percnurus*, *Morocco percnurus, Eupallasella percnurus* or *E. perenurus*. Considering the wide range of the species, the morphological variability described in the literature and the geographic isolation of some populations, a critical reassessment of the taxonomic status of these isolated populations is urgently needed.

Further reading. Berg, 1949: 574 (morphology, biology); Oliva, 1963 (morphology); Movchan & Smirnov, 1981: 166 (morphology, biology); Howes, 1985 (systematics); Boroń, in Brylińska, 2000: 303 (biology); Bogutskaya et al., 2005: 93 (nomenclature); Sakai et al., 2006 (phylogeny).



Rhynchocypris percnurus

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Rutilus

Rutilus includes medium-sized to large species, which inhabit lakes and lowland rivers. *Rutilus* are most diverse in the southern Balkans and their taxonomy is far from settled, with the the latest species newly described in early 2006. The ecological diversity of *Rutilus* ranges from the well-known eurytopic *R. rutilus* to cryptic species such as the almost unstudied *R. virgo*. As they are very abundant in many lacustrine and lowland water bodies, *Rutilus* are important parts of the food webs and play a key role in the structure of the ecosystems. The identification of *Rutilus* species is often complicated, especially since up to three species might occur together.

Key to species of *Rutilus* in Europe

Europe north of the Alps; Black and Caspian Sea basins

1a – Body almost cylindrical; 59–70 total lateral line scales. 2

1b – Body compressed; 41–46 total lateral line scales. 3

2a – Usually 53–64 + 3 lateral line scales; 9½ branched dorsal rays (Black and Caspian Sea basins, in Danube drainage, restricted to estuary). ..... *R. frisii*

2b – Usually 62–67 + 3–4 lateral line scales; 8–9½ branched dorsal rays (lakes of upper Danube drainage, in Austria and Germany). ..... *R. meidingeri*

3a – Usually 11–12½ branched anal rays; 44–46 total lateral line scales; mouth inferior; peritoneum black; breeding males with two horizontal rows of large tubercles on side of head. ..... *R. virgo*

3b – Usually 10½ branched anal rays; 41–44 total lateral line scales; mouth terminal to inferior; peritoneum pale grey; breeding males with scattered, small tubercles on side of head. 4

4a – Mouth terminal; pectoral, pelvic and anal orange to red; iris from yellow in juveniles to deep red in adults. ..... *R. rutilus*

4b – Mouth subterminal to inferior; pectoral, pelvic and anal hyaline to dark grey; iris whitish to pale yellow. 5

5a – Usually 9½ branched dorsal rays. ..... *R. caspicus*

5b – Usually 10½ branched dorsal rays. ..... *R. heckelii*

Apennine Peninsula

1a – 11½ branched anal rays; 46–49 total lateral line scales; peritoneum black; mouth inferior. ..... *R. pigus*

1b – 9–10½ branched anal rays; 36–44 total lateral line scales; peritoneum pale grey; mouth terminal or subterminal. 2

2a – 10½ branched dorsal rays; 10½ branched anal rays; no midlateral stripe; mouth terminal. ..... *R. rutilus*

2b – 8–9½ branched dorsal rays; 9½ branched anal rays; brownish midlateral stripe; mouth subterminal. 3

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3a – 8½ branched dorsal rays; eye silvery or bronze in life; brownish midlateral stripe faint; base of pelvic, pectoral and anal orange or red.
..... *R. rubilio*

3b – 9½ branched dorsal rays; eye red in life; brownish midlateral stripe conspicuous; base of pelvic, pectoral and anal greyish.
..... *R. aula*

Balkan Peninsula outside Black Sea basin

1a – A conspicuous brownish midlateral stripe (northern Adriatic basin).
..... *R. aula*

1b – No brownish midlateral stripe.
..... 2

2a – 10½ branched anal rays (Aegean Sea basin, from Pinios drainage eastward).
..... *R. rutilus*

2b – 8–9½ branched anal rays.
..... 3

3a – 8½ branched anal rays (Lakes Skadar, Šas, Prespa and Ohrid).
..... 4

3b – Usually 9½ branched anal rays (Greece, Dalmatia).
..... 6

4a – Snout angular; angle between mouth cleft and horizontal about 30–40°; lower profile of head angular at lower jaw articulation; body golden in life (Lakes Skadar, Šas and Ohrid).
..... *R. karamani*

4b – Snout rounded; angle between mouth cleft and horizontal about 15–25°; lower profile of head smoothly rounded at lower jaw articulation; body silvery in life.
..... 5

5a – 9½ branched dorsal rays; eye diameter 4–5 % SL, 19–22 % HL, 1.7–1.9 times in interorbital distance; body depth 27–31 % SL (Lakes Prespa).
..... *R. prespensis*

5b – 8½ branched dorsal rays; eye diameter 5–8 % SL, 23–29 % HL, 1.3–1.6 times in interorbital distance; body depth 23–28 % SL (Lakes Skadar and Ohrid).
..... *R. ohridanus*

6a – Snout blunt, rounded (Greece: Sperchios drainage).
..... *R.* sp. Sperchios

6b – Snout pointed, triangular.
..... 7

7a – 42–47 + 2–3 lateral line scales; usually 16–18 gill rakers (Greece: Kifissos drainage).
..... *R. ylikiensis*

7b – 35–41 + 2–3 lateral line scales; usually 9–14 gill rakers.
..... 8

8a – Usually 9–11 gill rakers; length of caudal peduncle 13–18 % SL, 1.5–2.1 times in HL; usually 38–39 total vertebrae (Dalmatia).
..... *R. basak*

8b – Usually 12–14 gill rakers; length of caudal peduncle 16–20 % SL, 1.1–1.4 times in HL; usually 40–41 total vertebrae (Greece: Acheloos and Louros drainages, introduced in Lake Pamvotis).
..... *R. panosi*

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Rutilus aula; Ticino, Switzerland; 65 mm SL.

Rutilus basak; Neretva, Bosnia-Herzegovina; ~100 mm SL.

Rutilus aula

Common name. Triotto.

Diagnosis. Distinguished from other species of *Rutilus* in Apennine Peninsula by: ● 9½ branched dorsal rays / ○ 9½ branched anal rays / ○ 36–42 (usually 38–39) total lateral line scales / ○ mouth subterminal / ○ pelvic, pectoral and anal greyish / ○ eye red in life / ○ conspicuous dark brown mid-lateral stripe from eye to caudal base. Size up to about 180 mm SL.

Distribution. Adriatic basin from Socca to Po drainages (Italy, Switzerland, Slovenia), small coastal streams at Zadar (Croatia). Widely introduced in Italy.

Habitat. Streams with slow current and dense vegetation, canals, swamps and lakes.

Biology. Gregarious. Lives up to 7 years. Spawns for the first time at 1–3 years. Spawns in May – July in small groups made of one female and several males. Eggs deposited on aquatic vegetation. Omnivorous; feeds mainly on insect larvae, other invertebrates, algae and aquatic macrophytes.

Conservation status. LC. Abundant, but locally declining following introduction of *Carassius gibelio*, *Ctenopharyngodon idella* and *Silurus glanis* (in lakes). Introduced populations locally

Rutilus aula

Rutilus basak

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Rutilus caspicus; Volga delta, Russia; ~100 mm SL.

responsible for extirpation of *R. rubilio*.
Further reading. Bianco & Taraborelli, 1985: 143 (description); Gandolfi et al., 1991: 132 (biology; as *R. erythrophthalmus*); Kottelat, 1997: 76 (systematics).

Rutilus basak

Common name. Plotica.
Diagnosis. Distinguished from other species of *Rutilus* in Balkan Peninsula by: O 8–9½ (usually 9½) branched anal rays / O 9½ branched dorsal rays / O snout pointed, triangular / O 35–41 + 2–3 lateral line scales / O length of caudal peduncle 13–18 % SL, 1.5–2.1 times in HL / O fins hyaline to greyish. Size up to about 145 mm SL.
Distribution. Croatia and Bosnia-Herzegovina: Lakes Prološko and Ričice, Vrljika drainage near Imotski, Bačina lakes, Neretva drainage (including Tihaljina, Trebižat, Hutovo Blato, and Trebišnjica systems).
Habitat. Inhabits a wide range of habitats, as warm streams and rivers with moderate to slow current, lakes, backwaters and artificial water bodies.
Biology. No data.
Conservation status. LC.
Further reading. Bianco & Taraborelli, 1985: 149 (description).

Rutilus caspicus

Common name. Vobla.
Diagnosis. Distinguished from other species of *Rutilus* in Caspian Sea basin by: O 39–48 (usually 42–44) total lateral line scales / O body laterally compressed, depth 24–37 % SL / O usually 9½ branched dorsal rays / O usually 10½ branched anal rays / O mouth subterminal / O snout rounded / O iris silvery grey / O pectoral, pelvic and anal grey with dark margins (sometimes slightly red in autumn, outside spawning season) / O breeding males with fine, scattered tubercles on top and side of head. Size up to 450 mm SL and 2 kg.
Distribution. Northern and northwestern Caspian Sea. For spawning, enters Volga, Ural, Emba, Terek and Kura drainages. In Volga, migrates through delta and southern zone of Volga-Akhtuba system, only few go as far upstream as Volgograd. In Terek, does not migrate beyond delta.
Habitat. Spends most of year in shallow brackish coastal waters. At sea, adults are most abundant at 2.5–4 m depth and 2–4 ‰ salinity during summer. Enters freshwater of estuaries, lagoons and lower reaches of large rivers to spawn.
Biology. Semi-anadromous. Lives up to 10 years. Spawns for the first time at 2–5 years. In September, adults move close to coasts and overwinter in shallow waters from middle of November until ice melts. Spawning migration commences in late March – early April at 1–3°C and peaks at 7–9°C. Spawns in April – May on shallow shores of coastal lakes and flooded areas at 10–17°C. Eggs are sticky, laid among plants. Annual spawner, but some females spawn only every second year. After spawning, adults return to sea where they join groups of immature juveniles, not travelling for long distances, staying in areas with high abundance of prey. Larvae migrate to sea, first passively, then actively. By August, juveniles reach coastal waters. While in river, juveniles feed on plankton (mostly Cladocera) and small benthic animals. At sea, they feed on oligochaetes and chironomid larvae, sometimes algae. At 1 year, starts to feed on molluscs and large benthic crustaceans. Adults also feed on crustaceans, worms and chironomid larvae.
Conservation status. LC.
Further reading. Berg, 1949: 513 (biology); Kazancheyev, 1981 (biology); Belyaeva et al., 1989 (biology).

Rutilus caspicus

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Rutilus frisii; Tajan, Iran; ~300 mm SL.

Rutilus frisii

Common name. Vyrezub.

Diagnosis. Distinguished from other species of *Rutilus* in Black and Caspian Sea basins by: ● body almost cylindrical / ● 53–64 + 3 lateral line scales / ● body depth 19–26 % SL / ● abdomen posterior to pelvics rounded / ○ snout rounded, stout / ○ mouth subterminal / ○ iris and fins grey or slightly yellowish / ○ breeding males with large, scattered tubercles on top and side of head / ○ 9–10½ branched dorsal rays. Size up to about 680 mm and 8 kg.

Distribution. Black and Azov Sea basins, absent from Danube and Kuban drainages; landlocked populations in Donl, resulting from dam construction; Caspian basin, from Terek to Atrek drainages, very rarely in northern Caspian basin (Volga [earlier up to Perm], Ural). Anatolia: Lake Iznik in Sea of Marmara basin.

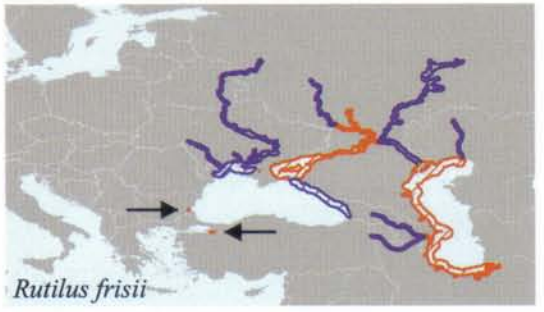
Habitat. Large brackish estuaries and their large, freshened plume waters, coastal lakes connected to rivers and lowland stretches of large rivers. In estuaries, in deep layers, down to 20 m. Tolerates salinities up to 7–12 ‰. Landlocked populations inhabit lakes or reservoirs. Spawns in small rivers or streams with heavy current on gravel bottom.

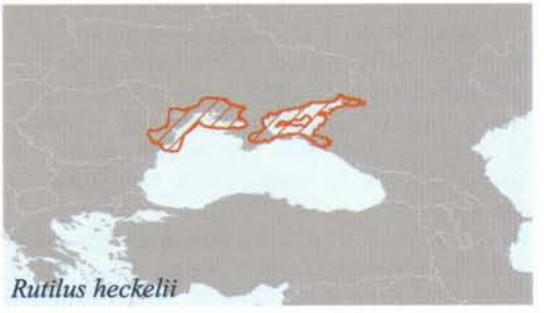
Biology. Semi-anadromous. Lives up to 12 years. Spawns for the first time at 4–5 years, 430–500 mm SL. Starts entering rivers in second half of October (Black Sea, rarely in Caspian Sea). When rivers are covered by ice, spawning migration ceases and resumes with the breaking up of the ice or even under ice in February – April. Spawns in April – May, earlier in southern drainages (February in Terek), when temperature reaches 8°C, peaking at 13–15°C. Eggs adhere to rocks and gravel, rarely to submerged plants. Adults return to estuaries to forage immediately after spawning. Eggs hatch in 10–16 days at 12–19°C. Juveniles migrate to estuaries during first summer (August). Landlocked populations migrate in spring from lakes or reservoirs or middle river stretches to tributaries or upper reaches. Larvae and early juveniles feed on zooplankton, algae and insect larvae. Adults feed mainly on molluscs and *Rhithropanopeus* crabs, supplemented by other benthic invertebrates. Stops feeding while migrating, spawning and overwintering.

Conservation status. LC. Migratory populations almost extirpated in Black Sea basin. In Caspian Sea, semi-anadromous populations sharply declined in the 1980sand may still continue to decline. Dams and large-scale overfishing make natural spawning in Caspian basin almost impossible and populations are maintained mainly by massive stocking. 120-140 millions juveniles are stocked annually in Iranian waters.

Remarks. In Caspian basin, a second species may be involved, entering only very lowest reaches of rivers, estuaries, coastal lakes and lagoons, where it spawns in shallow lagoons and lakes with slow current and dense vegetation on submerged plants.

Further reading. Berg, 1949: 532 (biology, morphology); Movchan & Smirnov, 1981 (Black Sea; biology); Kazancheyev, 1981 (Caspian Sea; biology); Magomedov, 1981 (Caspian Sea; biology); Belyaeva et al., 1989 (Caspian Sea; biology).





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Rutilus heckelii; Black Sea, Romania; ~150 mm SL.

Rutilus karamani; Lake Skadar, Montenegro; ~120 mm SL.

Rutilus heckelii

Common name. Taran.

Diagnosis. Distinguished from other species of *Rutilus* in Black Sea basin by: O 39–41 + 2–3 lateral line scales / O body laterally compressed / O usually 10½ branched dorsal rays / O usually 10½ branched anal rays / O mouth inferior / O iris from silvery to yellow / O pectoral, pelvic and anal grey with dark margins / O breeding males with scattered tubercles on head and a tubercle on each flank scale. Size up to 430 mm SL.

Distribution. Freshened areas of Black and Azov Seas, entering Don, Kuban, Dniepr, Dniestr and rarely Danube drainages.

Habitat. Spends most of year in shallow brackish coastal waters. While at sea, adults are most abundant at 2.5–4 m depth and 2–4 ‰ during summer. Enters freshwater of estuaries, lagoons and lower reaches of large rivers to spawn.

Biology. Semi-anadromous. Starts approaching coasts in August and entering rivers in September, with a peak in October. Ceases migration by end of November and overwinters in main river or estuaries. Spawning migration resumes with breaking up of ice in March (Dniepr). Spawns in April – May. Adults return to estuaries to forage immediately after spawning. Juveniles migrate to estuaries during first summer (August).

Conservation status. LC. Earlier declined due to blocking of almost all spawning rivers and decline of brackish areas in Black Sea basin. Still very abundant in Azov Sea basin.

Remarks. *R. heckelii* is not accepted as a valid species by most authors. Biological data indicate that semi-anadromous populations generally identified as *R. rutilus* are a distinct species in Black Sea basin. Fishermen along lower River South Bug distinguish between silvery, early spawning taran (*R. heckelii*) and later spawning red-eyed and red-finned roach (*R. rutilus*).

Further reading. Berg, 1949: 500 (biology, systematics); Holčík & Skorepa, 1971 (biology); Kottelat, 1997: 78 (systematics).

Rutilus karamani

Common name. Albanian roach.

Diagnosis. Distinguished from other species of *Rutilus* in Balkan Peninsula by: O 8½ branched anal rays / O 9½ branched dorsal rays / O snout angular / O angle between mouth cleft and horizontal about 30–40° / O lower profile of head angular at lower jaw articulation / O usually 35–37 + 2 lateral line scales / O eye diameter 5–7 % SL, 21–28 % HL, 1.3–1.6 times in interorbital dis-

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Rutilus meidingeri; Lake Attersee, Austria; ~400 mm SL. A. Hartl

tance / ○ pectoral, pelvic and anal yellowish, dorsal and caudal greyish / ○ body golden in life. Size up to about 190 mm SL.

Distribution. Lakes Skadar, Šas and Ohrid basins (Montenegro, Albania, Macedonia).

Habitat. Lacustrine, along shores. Also in lower parts of rivers and streams.

Biology. No data.

Conservation status. LC.

Further reading. Marić, 1989: 66 (description; as *R. prespensis vukovici*); Kottelat, 1997: 78 (systematics).

Rutilus meidingeri

Common name. Perlfisch.

Diagnosis. Distinguished from other species of *Rutilus* in Danube drainage by: ● body almost cylindrical / ● 62–67 + 3–4 lateral line scales / ● abdomen posterior to pelvics rounded / ○● breeding males with large, scattered tubercles on top and side of head / ○ snout rounded, stout / ○ mouth subterminal / ○ iris and fins grey or slightly yellowish / ○ 8–9½ branched dorsal rays. Size up to 600 mm SL.

Distribution. Austrian subalpine Lakes Attersee, Mondsee and Wolfgangsee. A small population in Austrian stretch of Danube. Extirpated in Lakes Traunsee (Austria) and Chiemsee (Germany). Stocked in Chiemsee. *Rutilus* populations of unclear identity from upper Tisza system (Slovakia, Hungary) might belong to this species.

Habitat. Subalpine lakes. Spawns in lake tributaries or streams connecting lakes.

Biology. Feeds on benthic invertebrates. Spawns in May – June, in shallow areas with current, near shore. In spawning season, males have conspicuous, strong, almost spiny, nuptial tubercles on head and upper half of body.

Conservation status. EN B1ab(i,ii,iii,iv,v) + 2ab (i,ii,iii,iv,v). Since 1980, vanished from two of five lakes it originally inhabited.

Further reading. Schiemer et al., 1994: 72 (biology).

Rutilus ohridanus

Common name. Ohrid roach.

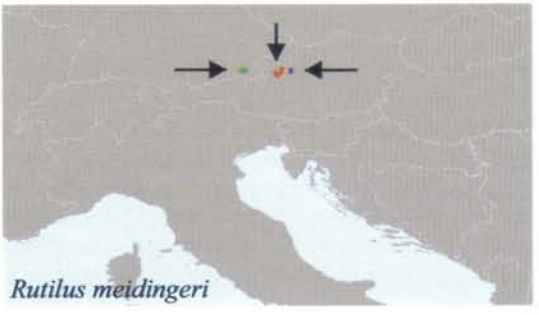
Diagnosis. Distinguished from other species of *Rutilus* in Balkan Peninsula by: ○ 8½ branched anal rays / ○ 8½ branched dorsal rays / ○ eye diameter 5–8 % SL, 23–29 % HL, 1.3–1.6 times in interorbital distance / ○ fins hyaline to greyish / ○ snout rounded / ○ angle between mouth cleft and horizontal about 15–25° / ○ lower profile of head smoothly rounded at lower jaw articulation / ○ 39–43 + 2–3 lateral line scales / ○ body silvery in life. Size up to about 130 mm SL.

Distribution. Lakes Ohrid (Macedonia, Albania) and Skadar (Montenegro, Albania).

Habitat. Lakes, along shores. Spawns over gravel and stones and in flooded areas. Also in warm rivers and streams, especially in stretches with moderate or no current.

Biology. Lives up to 7 years. Spawns in April – May. Eggs are sticky, yellow-orange and hatch in

Rutilus karamani



Rutilus meidingeri

watermanⓒ

Rutilus ohridanus; Lake Skadar, Montenegro; ~100 mm SL.

Rutilus panosi; Lake Trichonis, Greece; 113 mm SL.

9 days at 13–17°C. Feeds on plankton and plant material.

Conservation status. LC.

Further reading. Marić, 1989: 61 (description); Kottelat, 1997: 79 (systematics); Ivanovic, 1973: 80 (biology; as *R. rubilio*).

Rutilus panosi

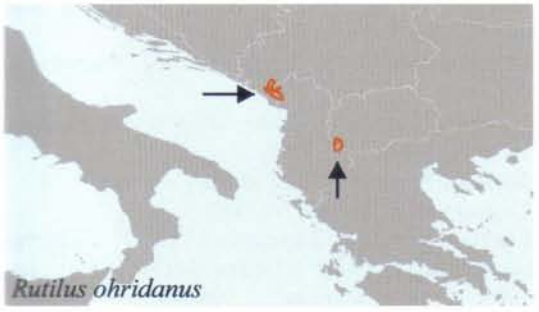
Common name. Acheloos roach.

Diagnosis. Distinguished from other species of *Rutilus* in Balkan Peninsula by: ♦ 40–41 + 3 lateral line scales / ♦ 9½ branched anal rays / ♦ 9½ branched dorsal rays / ♦ snout pointed, triangular / ♦ 8–9½ scale rows between lateral line and dorsal origin / ♦ 3–3½ scale rows between lateral line and pelvic base / ♦ length of caudal peduncle 16–20 % SL, 1.1–1.4 times in HL / ♦ body depth 24–27 % SL. Size up to about 240 mm SL.

Distribution. Greece: lakes of Acheloos and Louros drainages; introduced in Lake Pamvotis.

Habitat. Lacustrine; spawns in shallow and sandy areas, with vegetation.

Biology. Lives up to 10 years. Spawns for the first time at 3 years. Spawns once a year, in March – April, on plants or gravel. Eggs are very adhesive, 1.0–1.4 mm in diameter. Larvae and juve-



Rutilus ohridanus

Rutilus panosi

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Rutilus pigus; Lake Lugano, Switzerland; ~350 mm SL

niles are found away from shore. Juveniles feed on invertebrates and plant material, individuals larger than 120 mm SL feed mainly on snails and mussels.

Conservation status. VU D2.

Further reading. Daoulas & Economidis, 1984 (feeding; as *R. rubilio*); Daoulas & Kattoulas, 1985 (reproduction; as *R. rubilio*); Economou et al., 1994a: 21 (larvae; as *R. ylikiensis*); Bogutskaya & Iliadou, 2006: 294 (description).

Rutilus pigus

Common name. Pigo.

Diagnosis. Distinguished from other species of *Rutilus* in Apennine Peninsula by: ● 11½ branched anal rays / ○ 10½ branched dorsal rays / ○ 43–46 + 3 lateral line scales / ○ mouth inferior / ○ body laterally compressed, maximum width about 50 % of body depth / ● peritoneum black / ○ iris silvery / ● breeding males with two horizontal rows of distinct and separate tubercles on side of head above eye, lower one with 8–11 tubercles, upper one with 3–6 tubercles (tubercles reddish brown in ethanol); tubercles on body and head conical, sharply pointed, pointed slightly forward, occupying about ⅓ of exposed area of scale / ○ flanks golden bronze in life, marbled with darker patches / ○ snout conical. Size up to about 450 mm SL.

Rutilus pigus

Distribution. Northern Adriatic basin, from Livenza to Po drainages, Lakes Maggiore, Lugano and Como (Italy, Switzerland). Introduced in Arno.

Habitat. Lacustrine populations inhabit deep waters of large, subalpine lakes. Riverine populations inhabit large to medium sized rivers.

Biology. Lives in small groups. Lives up to 10 years. Spawns for the first time at 2–3 years. Moves to shallow areas of rivers to spawn in April – June. Feeds on invertebrates, algae and detritus.

Conservation status. LC. Threatened by overfishing and construction of weirs, which block access to spawning sites.

Further reading. Bianco & Taraborelli, 1985: 152 (description); Gandolfi et al., 1991: 124 (biology).

Rutilus prespensis

Common name. Prespa roach.

Diagnosis. Distinguished from other species of *Rutilus* in Balkan Peninsula by: ○ 8½ branched anal rays / ○ 9½ branched dorsal rays / ○ eye diameter 4–5 % SL, 19–22 % HL, 1.7–1.9 times in interorbital distance / ○ body depth 27–31 % SL / ○ fins hyaline to greyish, tip of anal and pelvic yellowish / ○ snout rounded / ○ angle between mouth cleft and horizontal about 15–25° / ○ lower profile of head smoothly rounded at lower jaw articulation / ○ 38–42 + 3 lateral line scales. Size up to about 170 mm SL.

Distribution. Lakes Prespa (Greece, Macedonia, Albania).

Habitat. Lacustrine, along shores and in shallow, swampy areas.

Biology. Spawns in lake in May – June.

Conservation status. VU D2.

Further reading. Karaman, 1924: 57 (description); Marić, 1989: 65 (description); Kottelat, 1997: 80 (systematics).

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Rutilus prespensis; Lake Prespa, Greece; 89 mm SL.

Rutilus rubilio; Lago di Fondi, Italy; ~90 mm SL.

Rutilus rubilio

Common name. Rovella.

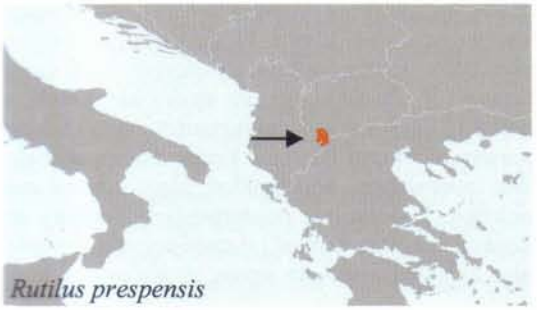
Diagnosis. Distinguished from other species of *Rutilus* in Apennine Peninsula by: ● 8½ branched dorsal rays / ○ 9½ branched anal rays / ● base of all fins red, except caudal / ○ 37–42 (usually 39–40) total lateral line scales / ○ mouth subterminal / ○ eye silvery or bronze in life / ○ brownish midlateral stripe from eye to caudal base, usually not very distinct. Size up to about 180 mm SL.

Distribution. Italy: Tyrrhenian slope from Magra to Bussento drainages, Adriatic slope from Chienti to Trigno drainages and Ofanto drainage. Introduced to southern Italy and Sicily; part of range on Adriatic slope and southernmost localities on Tyrrhenian slope possibly results from introductions.

Habitat. Streams with moderate current, shallow, sand or gravel bottom, and limited aquatic vegetation.

Biology. Gregarious. Lives up to 6 years. Spawns for the first time at 1–2 years. Spawns in April – June, when temperature reaches 16°C, in clear, shallow water, on gravel and aquatic vegetation, on sunny days. A single female usually spawns with 2–5 males. Multiple spawner. Feeds on small molluscs and crustaceans, insects and algae.

Conservation status. NT. Vanished from several



Rutilus prespensis

Rutilus rubilio

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Rutilus rutilus; Danube drainage, Germany; ~200 mm SL. A. Hartl

localities in central Italy following introduction of *R. aula* and other cyprinids. In southern Italy, where introduced, is responsible for decline of native *Alburnus albidus*.

Further reading. Bianco & Taraborelli, 1985: 136 (description); Bianco, 1995a: 165 (distribution).

Rutilus rutilus

Common name. Roach.

Diagnosis. Only species of *Rutilus* in Atlantic basin north of Pyrénées. Distinguished from other species of *Rutilus* in Black and Caspian Sea basins and Apennine Peninsula by: ○ 39–41 + 2–3 (41–44 total) lateral line scales / ○ body laterally compressed, depth 25–35 % SL / ○ 10½ branched dorsal rays / ○ 10½ branched anal rays / ○ mouth terminal / ○ snout pointed / ○ iris from yellow in juveniles to deep red in adults / ○ pectoral, pelvic and anal orange to red / ○ no midlateral stripe. Distinguished from other species of *Rutilus* in Balkan Peninsula by: ● 10½ branched anal rays. Size up to 500 mm SL.

Distribution. Europe north of Pyrénées and Alps, eastward to Ural and Eya drainages (Caspian basin). Aegean basin, in Pinios, Vardar, Vegoritis, Kastoria, Struma and Maritza drainages. Asia: Marmara basin and lower Sakarya in Anatolia, Aral basin and Siberia from Ob eastward to Lena drainages. Naturally absent from Iberian Peninsula, Adriatic basin, Italy, Great Britain north of 56°N, Scandinavia north of 69°N. Locally introduced in Spain. Introduced and invasive in northeastern Italy.

Rutilus rutilus

Habitat. In a wide variety of habitats, mainly in lowland areas. Most abundant in nutrient-rich lakes and large to medium sized rivers and backwaters. Takes advantage of channelization, damming and slight organic pollution. Known also from small lowland streams and from brackish coastal lagoons. In fast-flowing rivers, restricted to stretches where backwaters or shelters allow for overwintering. Spawns among dense submerged vegetation in backwaters or lakes, flooded meadows or in shallow, fast-flowing river habitats on plant or gravel bottom.

Biology. Lives up to 13 years. Males reproduce for the first time at 2–3 years, females 1 year later, usually at about 100 mm SL. Undertakes short spawning migrations, sometimes starting as early as September, usually with a peak at temperatures above 9°C in spring. Spawns in April – May, when temperature rises above 12°C. Usually, a whole population spawns within a period of 5–10 days. Spawns in shoals. Eggs are sticky and hatch in about 12 days. Larvae and juveniles inhabit a wide variety of littoral habitats. Feeds mainly on benthic invertebrates, zooplankton, plant material and detritus. Populations predominantly feeding on detritus are often stunted (stunted populations may also be associated with strong year classes). May

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Hybrids in Cyprinidae

About 62 different natural hybrids between species of European Cyprinidae are described, mostly between different leuciscine genera. Hybrids between different species of *Barbus* are common in some areas. Some leuciscine hybrids occur so frequently in natural waters that many were described as valid species with large ranges. In particular, the hybrids *Abramis brama* × *Rutilus rutilus* and *Squalius* spp. × *Alburnus* spp. are recorded from almost every water body in which the parental species occur. Cyprinid hybrids are usually rare, but in some cases they may be more abundant than the parental species. Leuciscine hybrids are generally fertile. In laboratory, they usually produce viable progeny if crossed among themselves or with the parental species. Hybrids of the second or later generations are very rarely observed in the wild. Mt-DNA introgression of *Squalius tenellus* into *Scardinius dergle* demonstrate the reciprocal fertility of some hybrids in the wild. The morphology of hybrids is usually very homogenous and intermediate between those of the parental species. The mechanisms preventing cyprinid hybrids from forming hybrid swarms with a wide range of morphologically heterogeneous F_2 hybrids are only partly known. Male *A. brama* × *R. rutilus* hybrids are known to produce three types of spermatozoids, haploid gametes of *R. rutilus*, haploid gametes of *A. brama* and diploid gametes with the unreduced chromosome complement of the hybrid. This results in F_2 progeny comprising only of diploid and triploid F_1 hybrids and pure parental species.

Hybridisation has played a main role in speciation in at least two species of European freshwater cyprinids, *Iberocypris alburnoides* and *I. palaciosi*. Hybridisation is also important in *Cobitis* loaches.
Further reading. Freyhof et al., 2005 (hybrids).

Hybrid *Abramis brama* x *Rutilus rutilus*; Rhine drainage, Germany; ~200 mm SL.

shift from littoral to pelagic habitats and between benthic food and zooplankton when abundance of a specific food item is high or in order to avoid predation and/or competition. The decision whether to stay in open water or among littoral vegetation is often described as a trade-off between food uptake and predator avoidance. When growing, there is an energetic need to switch from zooplankton to benthic food (chironomids, molluscs). Individuals able to feed on *Dreissena* mussels increase their growth rate but do not exploit this food source until they have reached about 120 mm SL (at which size they are able to crush the mussels). In some areas (Volga reservoirs), pelagic and benthic roach can be distinguished by life-history traits (spawning time, spawning sites). Overwinters in backwaters or in deep parts of lakes. Frequently produces fertile hybrids with *Abramis brama*.
Conservation status. LC.
Further reading. Holčík & Skorepa, 1971 (morphology); Kottelat, 1997: 80 (systematics).

Rutilus virgo

Common name. Cactus roach.
Diagnosis. Distinguished from other species of *Rutilus* in Danube drainage by: ● usually 11–12½ branched anal rays / ○ 44–46 total lateral line scales / ○ mouth inferior / ○ body laterally compressed, maximum body width about 50 % of body depth / ○ iris silvery / ● peritoneum black /

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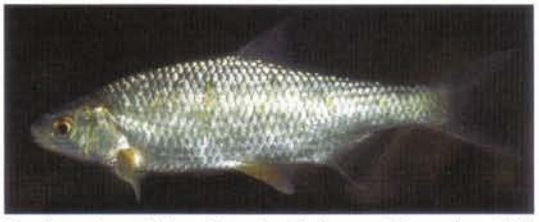
Rutilus virgo; Krka, Danube drainage, Slovenia; ~350 mm SL.

Rutilus virgo; Krka, Danube drainage, Slovenia; ~350 mm SL; tubercles on head.

Rutilus virgo; Krka, Danube drainage, Slovenia; ~350 mm SL; tubercles on body.



Rutilus virgo; Krka, Danube drainage, Slovenia; ~130 mm SL.

● breeding males with two horizontal rows of large tubercles on side of head above eye, usually more or less fused into a continuous ridge (tubercles white in ethanol); tubercles on body massive, occupying most of scale area / ○ body greenish to bluish brown / ○ snout blunt. Size up to about 400 mm SL.

Distribution. Danube drainage upriver of Iron Gate; most abundant in Save drainage.

Habitat. Medium sized to large rivers. Spawns over gravel or submerged plants in fast-flowing water of riffles.

Biology. Spawns at 10–14°C in March – May. Biology almost unknown.

Conservation status. LC.

Further reading. Misik, 1957 (morphology).

Rutilus ylikiensis

Common name. Yliki roach.

Diagnosis. Distinguished from other species of *Rutilus* in Balkan Peninsula by: ● 42–47 + 2–3 lateral line scales / ○ 9½ branched anal rays / ○ usually 9½ branched dorsal rays / ○ snout pointed, triangular / ○ 8½ scale rows between lateral line and dorsal origin / ○ 5 scale rows between lateral line and pelvic base / ○ body depth 27–31 % SL. Size up to about 160 mm SL.

Distribution. Greece: Kifissos drainage, including Lakes Yliki and Paralimni.

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Rutilus ylikiensis; Lake Yliki, Greece; 129 mm SL.

Rutilus sp. Sperchios; Sperchios drainage, Greece; 84 mm SL.

Habitat. Lacustrine.
Biology. Spawns in February – April.
Conservation status. EN B1ab(i,ii,iii,iv,v).
Further reading. Stephanidis, 1939b: 55 (description).

Rutilus sp. Sperchios

Common name. Sperchios roach.
Diagnosis. Distinguished from other species of *Rutilus* in Balkan Peninsula by: ✪ 40 + 3 lateral line scales / ✪ 9½ branched anal rays / ✪ 9½ branched dorsal rays / ✪ snout blunt, rounded / ✪ 6½ scale rows between lateral line and dorsal origin / ✪ 4 scale rows between lateral line and pelvic base. Size up to at least 150 mm SL.

Distribution. Greece: Sperchios basin.
Habitat. Swamps and slowly flowing water.
Biology. No data.
Conservation status. DD**. Possibly CR B2ac(ii,iii,v), know only from two individuals collected in 1997.
Further reading. No published information.

Rutilus ylikiensis

Rutilus sp. Sperchios

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Scardinius

Scardinius are small to medium size fishes living in habitats ranging from lakes to slow-flowing large rivers, usually associated with submerged vegetation. Several species are characterised by dark grey fins in adults. While this character is easily recognised, the colour rapidly fades in preserved individuals. Also, juveniles of some black-fin species have orange or red fins which change to black in adults. Similarly, the diagnostic head shapes are hardly visible in juveniles. Therefore, only adults larger than 100 mm SL can be identified with the key (except for *Scardinius racovitzai*, which does not reach this size). All species are allopatric and the geographic origin is a good starting point for identification.

Key to species of *Scardinius* in Europe

1a – Dorsal head profile conspicuously concave; back distinctly humped behind nape in adults; snout pointing upward. 2

1b – Dorsal head profile straight to slightly concave; no distinct hump on back behind nape; snout conical, pointing forward. 4

2a – 17–24 gill rakers; articulation of lower jaw under or behind anterior margin of eye. ..... *S. graecus*

2b – 10–17 gill rakers; articulation of lower jaw in front of anterior margin of eye. 3

3a – Juveniles less than about 70 mm SL with a dark midlateral stripe; in lateral view, eye close to or flush with dorsal head profile; 37–42 + 2–3 lateral line scales; usually 10½ branched anal rays; 12–17 gill rakers. ..... *S. acarnanicus*

3b – No dark lateral stripe; in lateral view, eye not close to dorsal head profile; 34–37 + 2–3 lateral line scales; 9½ branched anal rays; 10–12 gill rakers. ..... *S. knezevici*

4a – All fins with reddish hue, pelvic deep red in adults or individuals larger than 100 mm SL. 5

4b – All fins dark grey in adults larger than 100 mm SL. 6

5a – Head and body compressed, head width 13–14 % SL; head length 24–28 % SL; depth of caudal peduncle 1.5–2.0 times in its length. ..... *S. erythrophthalmus*

5b – Head and body compact, head width 15–17 % SL; head length 28–31 % SL; depth of caudal peduncle 1.3–1.7 times in its length. ..... *S. racovitzai*

6a – Ventral profile of head without conspicuous angle at articulation of lower jaw. 7

6b – Ventral head profile with a conspicuous angle at articulation of lower jaw. 8

7b – 9–10½ branched anal rays; body depth 31–36 % SL. ..... *S. scardafa*

7b – 10–12½ branched anal rays; body depth 35–39 % SL. ..... *S. hesperidicus*

8b – 9½ branched anal rays; 37–40 total lateral line scales. ..... *S. plotizza*

8b – 10½ branched anal rays; 40–43 total lateral line scales. ..... *S. dergle*

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Scardinius acarnanicus; Lake Trichonis, Greece; 147 mm SL.

Scardinius dergle; Lake Buško, Bosnia-Herzegovina; ~90 mm SL.

Scardinius acarnanicus

Common name. Trichonis rudd.

Diagnosis. Distinguished from other species of *Scardinius* in Balkan Peninsula by: ○ dorsal head profile conspicuously concave, snout pointing upward, tip above level of middle of eye / ○ in lateral view, eye close to or flush with dorsal head profile / ○ articulation of lower jaw in front of anterior margin of eye / ○ head length 24–30 % SL / ○ usually 10½ branched anal rays / ○ 13–16 pectoral rays / ○ 12–17 gill rakers / ● juveniles less than about 70 mm SL with a dark mid-lateral stripe / ○ 37–42 + 2–3 lateral line scales. Size up to 280 mm SL.

Distribution. Greece: lower Acheloos drainage, including lakes.

Habitat. In lakes and large rivers.

Biology. Lives up to 7 years. Spawns for the first time at 140–180 mm at 2–3 years. Fractional spawner. Spawns in March – July. Deposits adhesive eggs on vegetation. Eggs hatch in 5 days. Early larvae and juvenile often form large schools, often mixed with *Tropidophoxinellus hellenicus*. Phytophagous, juveniles feed on phytoplankton, adults on macrophytes.

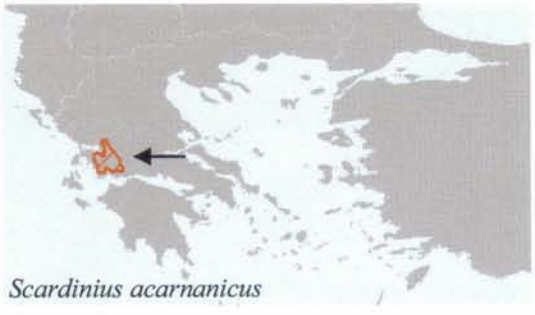
Conservation status. NT.

Further reading. Iliadou & Ondrias, 1980 (biology; as *S. erythrophthalmus*); Iliadou, 1991 (feeding); Economou et al., 1994a: 20 (reproduction, larvae); Iliadou et al., 1996 (morphology).

Scardinius dergle

Common name. Bulldog rudd.

Diagnosis. Distinguished from other species of *Scardinius* in Balkan Peninsula by: ○ dorsal head profile straight, snout pointing forward, tip at or slightly below level of middle of eye / ○ back not humped behind nape / ○ in lateral view, eye not close to dorsal head profile / ○ articulation of lower jaw below or in front of anterior margin of eye / ○ lower head profile with a conspicuous angle at articulation of lower jaw / ○ head length 28–32 % SL / ○ body depth 28–38 % SL / ○ depth of caudal peduncle 10–11 % SL / ○ 10½ branched



Scardinius acarnanicus

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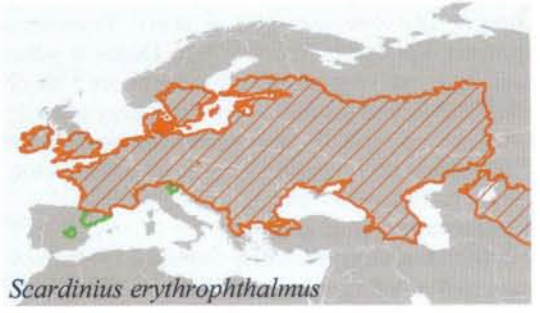
Scardinius erythrophthalmus; Danube, Germany; ~200 mm SL. A. Hartl

anal rays / O 10–13 gill rakers / O 40–43 lateral line scales / O all fins dark grey in adults larger than 60 mm SL. Size up to at least 150 mm SL.
Distribution. Karstic streams in Livanjsko polje, Lakes Buško and Mandečko near Livno, Šarena lakes at Knin, Krka and Cetina basins.
Habitat. Slow-flowing and still waters and lakes.
Biology. No data.
Conservation status. NT.
Further reading. Heckel & Kner, 1858: 156 (description); Freyhof et al., 2005b (genetics).

Scardinius erythrophthalmus

Common name. Rudd.
Diagnosis. Distinguished from other species of *Scardinius* in Europe by: O dorsal head profile straight or slightly convex, snout pointing forward, tip at or slightly above level of middle of eye / O back not humped behind nape / O in lateral view, eye not close to dorsal head profile / O articulation of lower jaw in front of anterior margin of eye / O 10–13½ branched anal rays / O 39–42 total lateral line scales / O 9–12 gill rakers / O all fins with reddish hue, pelvic deep red / O head and body compressed, head width 13–14 % SL / O head length 24–28 % SL / O depth of caudal peduncle 1.5–2.0 times in its length, 11–12 % SL. Size up to 350 mm SL.
Distribution. Most European rivers north of Pyrénées and Alps, eastward to Ural and Eya drainages, Aral and White Sea basins; Black Sea basin in Europe and northern Asia Minor. Naturally absent from Iberian Peninsula, Adriatic basin, Italy, Greece south of Pinios drainage, Great Britain north of 54°N, Ireland and Scandinavia north of 62°N. Introduced to Spain and Corsica.
Habitat. Mainly nutrient-rich, well vegetated lowland rivers, backwaters, oxbows, ponds and lakes. Spawns on roots or submerged plants.
Biology. Lives up to 17 years. Spawns for the first time at 3–4 years. Fractional spawner. Spawns in April – July, when temperature rises above 15°C. Males assemble at spawning grounds and drive ripe females, often with much splashing, into dense vegetation to spawn. Eggs are very sticky. Feeds predominantly on plankton, terrestrial insects and plant material. Able to adapt to unfavourable environmental conditions by slow growth and small

Scardinius dergle



Scardinius erythrophthalmus

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Scardinius graecus; Lake Yliki, Greece; 161 mm SL.

size at maturity (stunted populations).
Conservation status. LC.
Further reading. Bănărescu, 1964 (biology).

Scardinius graecus

Common name. Yliki rudd.
Diagnosis. Distinguished from other species of *Scardinius* in Balkan Peninsula by: O dorsal profile of head conspicuously concave, tip of snout about level of middle of eye / O articulation of lower jaw below or behind anterior margin of eye / O in lateral view, eye close to dorsal head profile / O head length 24–35 % SL / O body depth 20–30 % SL / O usually 11½ branched anal rays / O 14–18 pectoral rays / O 17–24 gill rakers / O 38–43 + 2–3 lateral line scales. Size up to 360 mm SL.
Distribution. Greece: Lake Yliki. Previously in Lake Paralimni, which is now drained.
Habitat. Lacustrine.
Biology. Fractional spawner. Spawns in March – June. Adhesive, spherical, yellow eggs are deposited among vegetation. Eggs hatch in 4 days at 25°C.
Conservation status. CR B1ab(i,ii,iii,v) + 2ab (i,ii,iii,v).
Further reading. Iliadou et al., 1996 (morphology); Barbieri-Tseliki et al., 1996 (reproduction).

Scardinius hesperidicus

Common name. Italian rudd.
Diagnosis. Distinguished from other species of *Scardinius* in Mediterranean basin by: O dorsal head profile straight or slightly convex / O snout pointing forward, tip at or slightly above level of middle of eye / O back not humped behind nape / O in lateral view, eye not close to dorsal head profile / O articulation of lower jaw in front of anterior margin of eye / O head profile without conspicuous angle at articulation of lower jaw / O head length 24–27 % SL / O body depth 35–39 % SL / O depth of caudal peduncle 11–12 % SL / O 10–12½ branched anal rays / O 36–39 + 2–3 lateral line scales / O all fins dark grey in adults larger than 100 mm SL. Size up to about 400 mm SL.
Distribution. Adriatic and Tyrrhenian basins in Slovenia, Italy and Switzerland. Widely introduced in Italy. Most likely only native in Po drainage and Adriatic rivers east of Po.
Habitat. In well vegetated lowland rivers, backwaters, oxbows, ponds and lakes. Spawns on submerged plants.
Biology. Lives up to 15 years. Spawns for the first time at 2–3 years. Fractional spawner. Spawns in March – July, when temperature rises above 18°C. Feeds predominantly on macrophytes and terrestrial insects.
Conservation status. LC. May form locally hybrid populations with introduced *S. erythrophthalmus*.
Further reading. Bruno, 1987 (biology, distribution; as *S. erythrophthalmus*).

Scardinius graecus

Scardinius hesperidicus

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Scardinius hesperidicus; Piave drainage, Italy; ~150 mm SL. A. Hartl

Scardinius knezevici; Lake Skadar, Montenegro; ~200 mm SL.

Scardinius knezevici

Common name. Skadar rudd.

Diagnosis. Distinguished from other species of *Scardinius* in Balkan Peninsula by: ○ 34–37 + 2–3 lateral line scales / ○ 9½ branched anal rays / ○ all fins greyish / ○ back humped behind nape / ○ articulation of lower jaw in front of anterior margin of eye / ○ in lateral view, eye not close to dorsal head profile / ○ 10–12 gill rakers. Size up to about 260 mm SL.

Scardinius knezevici

Distribution. Lakes Ohrid (Macedonia, Albania) and Skadar (Montenegro, Albania).

Habitat. Deep pools and canals in swampy areas along lake shores or in floodplain.

Biology. Spawns in April – May.

Conservation status. VU D2*, apparently now rare in Lake Ohrid but abundant in Lake Skadar.

Further reading. Vladykov & Petit, 1930: 399 (description); Grupče & Dimovski, 1984 (description, as *S. scardafa*); Bianco & Kottelat, 2005: 232 (description).

Scardinius plotizza

Common name. Neretva rudd.

Diagnosis. Distinguished from other species of *Scardinius* in Europe by: ○ dorsal head profile straight, snout pointing forward, tip above level of middle of eye / ○ back not humped behind nape / ○ in lateral view, eye not close to dorsal head profile / ○ head length 29–31 % SL / ○ 11–

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Scardinius plotizza; Neretva delta, Croatia; 160 mm SL.

Scardinius racovitzai; Petzea, Danube drainage, Romania; ~60 mm SL.

14 gill rakers / ○ 37–40 total lateral line scales / ○ 9½ branched anal rays / ○ articulation of lower jaw below or in front of anterior margin of eye / ○ ventral head profile with a conspicuous angle at articulation of lower jaw / ○ all fins dark grey in adults. Size up to about 200 mm SL.

Distribution. Bosnia-Herzegovina, Croatia: middle and lower Neretva drainage, Stara (Old) Neretva, Lake Desne, lake basins near Imotski, Matica drainage near Vrgorac.

Habitat. In well vegetated rivers, backwaters, oxbows, ponds and lakes.

Biology. No data.

Conservation status. LC.

Further reading. Heckel & Kner, 1858: 156 (description).

Scardinius racovitzai

Common name. Petzea rudd.

Diagnosis. Distinguished from *Scardinius erythrophtalmus* by: ○ head and body compact, head width 15–17 % SL (vs. 13–14) / ○ head length 28–31 % SL (vs. 24–28) / ○ depth of caudal peduncle 1.3–1.7 times in its length (vs. 1.5–2.0). Size up to 85 mm SL.

Distribution. Western Romania: hot spring Petzea (or Baile Epiropesti) close to Oradea, about 10,000 m^2.

Habitat. Densely vegetated, shallow hot spring with mud bottom.

Biology. No data.

Conservation status. CR B1ab(ii,iii) + 2ab(ii,iii).

Scardinius plotizza

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Scardinius scardafa; Lake Scanno, Italy; ~220 mm SL.

Further reading. Müller, 1958: 165 (description); Bănărescu, 1964: 355 (distribution, biology); Kottelat, 1997: 84 (systematics).

Scardinius scardafa

Common name. Tiber rudd.

Diagnosis. Distinguished from other species of *Scardinius* in Mediterranean basin by: ○ 9–10½ branched anal rays / ○ 37–40 total lateral line scales / ○ 12–14 gill rakers / ○ body depth 31–36 % SL / ○ ventral head profile without conspicuous angle at articulation of lower jaw / ○ all fins dark grey. Size up to about 350 mm SL.

Distribution. Italy: Tyrrhenian basin from Magra to Garigliano drainages; apparently introduced in Lake Scanno (Italy, Pescara drainage), which is the only locality where it is known to survive. It also survived some time in Lake Massaciuccoli (Italy, Serchio drainage [north of Pisa]) but the present status of this population is not known.

Habitat. Lakes, swamps, in or near aquatic vegetation.

Biology. Spawns in April – June.

Conservation status. CR A3e (but may actually qualify as EW). Survives only in Lake Scanno, where it is abundant and apparently stable. Threatened by proposed stocking of *S. hesperidicus* and other cyprinids.

Further reading. Bonaparte, 1837 (description); Bianco, 1994: 455 (distribution), 1995: 165, 2004: 246 (conservation); Bianco et al., 2001 (diagnosis).

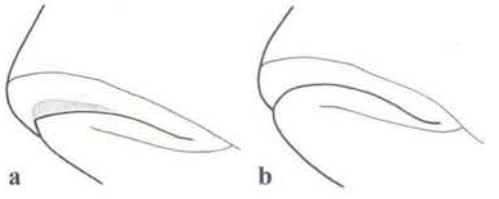

Figure 47 Head of *Squalius* species; **a,** upper lip, projecting, enclosing tip of upper jaw; **b,** upper lip not projecting.

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Squalius

Squalius are small to large fishes living in habitats ranging from lakes and slow-flowing large rivers to hill streams. Species of *Squalius* are characterised by the absence of a scaleless midventral keel in front of the anus, a complete lateral line, usually a terminal or subterminal mouth, the dorsal origin behind pelvic base, two rows of pharyngeal teeth, the absence of a prominent dark lateral stripe, 8–11½ branched anal rays and 7–9½ branched dorsal rays. The systematics of *Squalius* is still not resolved. Several species of southern Europe have quite similar appearances and earlier authors had very contradictory views on species definitions; at some time, most were identified as a wide-ranging *S. cephalus*. Recent genetic data have shown that many southern European taxa recognized by earlier authors are indeed distinct. Unfortunately, most of these genetic studies lacked the conceptual tools to reach operational taxonomic conclusions.

Keys to species of *Squalius* in Europe

Black, Caspian, Baltic and North Sea basins, Atlantic basin north of Pyrénées

1a – 36–41 + 3 lateral line scales; interorbital distance 32–35 % HL; postorbital distance 45–47 % HL; eye diameter 22–26 % HL, 1.3–1.5 times in snout length (Kuban).
..... *S. aphipsi*

1b – 40–46 + 2–3 lateral line scales; interorbital distance 37–42 % HL; postorbital distance 47–51 % HL; eye diameter 17–22 % HL, 1.5–2.3 times in snout length.
..... 2

2a – Mouth slightly subinferior, tip of lower jaw included in upper lip (Fig. 47a); dorsal profile with no or little marked discontinuity between head and trunk (Fig. 48a); in addition to black edge, brown pigments on scales, denser on upper and lower tips of exposed part, often forming faint longitudinal stripes between scale rows (Fig. 49d); dorso-hypural distance falling at or behind posterior margin of eye when reported forward; distance between tips of first and last branched anal rays about equal to depth of caudal peduncle in individuals larger than 150 mm SL (Spain: Ebro drainage; France: Tech and Agly drainages).
..... *S. laietanus*

2b – Mouth terminal, with well marked chin; tip of lower jaw not included in upper lip (Fig. 47b); dorsal profile with a well-marked discontinuity between head and trunk (Fig. 48b); except for black edge, no or few pigments on scales, forming a clearly contrasted reticulate pattern; dorso-hypural distance usually falling at or in front of posterior margin of eye when reported forward; distance between tips of first and last branched anal rays (with the fin stretched out) conspicuously greater than depth of caudal peduncle in individuals larger than 150 mm SL.
..... *S. cephalus*

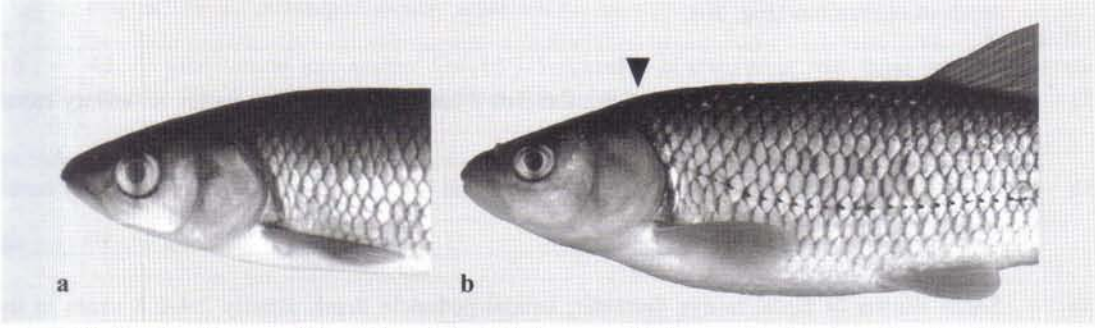

Figure 48 *Squalius laietanus* (**a**) and *S. cephalus* (**b**). Arrow points to discontinuity along dorsal profile between head and trunk.

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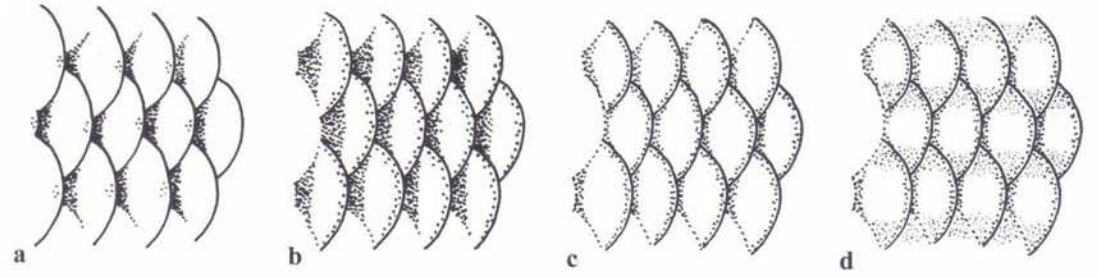

Figure 49 Pigments on scales of *Squalius* species: **a,** dark spot on scale pocket (on anterior half of exposed field of scale); **b,** pigments along free margin and dark spot on scale pocket; **c,** pigments along free margin of each scale; **d,** pigments denser on upper and lower extremities of exposed part of scales (**a-c** after Bogutskaya & Zupančič, 1999).

Iberian Peninsula

This key is tentative. For a number of species the published morphological data are not explicit enough to allow the elaboration of a more robust key.

1a – 33–40 + 2 lateral line scales.
..... 2

1b – 37–45 + 2–3 lateral line scales.
..... 4

2a - 4 scale rows between lateral line and pelvic origin.
..... *S. valentinus*

2a - 1½–3 scale rows between lateral line and pelvic origin.
..... 3

3a – Snout rounded; mouth subterminal, upper jaw projecting; head length less than body depth; 2½–3 scale rows between lateral line and pelvic origin.
..... *S. aradensis*

3b – Snout pointed; mouth terminal; head length greater than body depth (except in some large individuals); 1½–2½ scale rows between lateral line and pelvic origin.
..... *S. torgalensis*

4a – A row of black pigments along free margin of each flank scale, forming a regular reticulate pattern and brown pigments on scales, denser on upper and lower extremities of exposed part, often forming faint longitudinal stripes between scale rows (Fig. 49d); length of lower jaw greater than depth of operculum (Fig. 50).
..... *S. laietanus*

4b – A dark spot on scale pocket of each flank scale (Fig. 49a); length of lower jaw smaller than depth of operculum (Fig. 50).
..... 5

5a – Infraorbital bones narrow, width of infraorbitals 2 and 5 about 2 times width of sensory canal on same bones (Fig. 51a).
..... *S. carolitertii*

5b – Infraorbital bones broad, width of infraorbitals 2 and 5 about 4–5 times width of sensory canal on same bones (Fig. 51b).
..... 6

6a – Snout shorter or equal to eye diameter; caudal peduncle depth usually 2.4–2.8 times in its length.
..... *S. malacitanus*

6b – Snout longer than eye diameter; caudal peduncle depth usually 2.0–2.6 times in its length.
..... *S. pyrenaicus*

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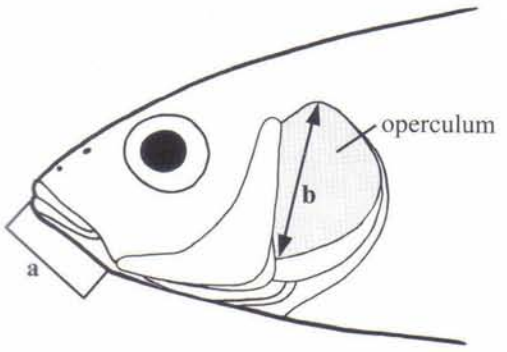

Figure 50 Relation between length of lower jaw (**a**) and depth of operculum (**b**) in leuciscine species.

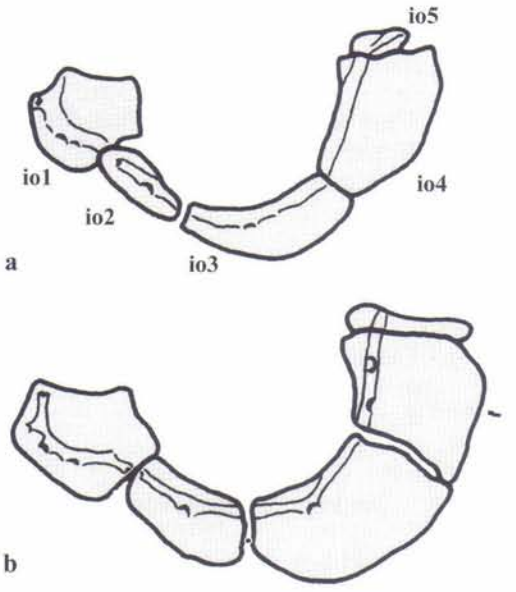

Figure 51 Infraorbital bones of *Squalius* species: **a,** *S. carolitertii*; **b,** *S. pyrenaicus*. **io1-5,** infraorbitals 1-5 (after Doadrio, 1988).

Apennine Peninsula

1a – 7½ branched dorsal rays; 37–40 + 3 lateral line scales.
..... *S. lucumonis*

1b – 8–9½ branched dorsal rays; 40–46 + 2–3 lateral line scales.
..... 2

2a – Body depth 19–23 % SL; only very faint black pigments along free margin of flank scales above lateral line; snout pointed.
..... *S. albus*

2b – Body depth 22–27 % SL; a row of black pigments along free margin of each flank scale, forming a regular reticulate pattern; snout blunt.
..... *S. squalus*

East Adriatic basin (south to Skadar-Ohrid-Drin drainage)

1a – 76–85 total lateral line scales; ½15–17/1/6–7 scales in transverse row from dorsal to pelvic origins; 28–32 circumpeduncular scale rows.
..... *S. tenellus*

1b – 42–75 total lateral line scales; ½9–15/1/5–6 scales in transverse row from dorsal to pelvic origins; 16–26 circumpeduncular scale rows.
..... 2

2a – 67–75 total lateral line scales.
..... *S. microlepis*

2b – 42–54 total lateral line scales
..... 3

3a – 5th infraorbital bone very large (Fig. 52a).
..... *S. squalus*

3b – 5th infraorbital bone small or absent (Fig. 52b).
..... 4

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4a - Pigments usually absent along free margin of flank scales; a conspicuous dark spot on scale pocket of each flank scale above lateral line (Fig. 49a); eye diameter 24–28 % HL; snout elongate.
..... *S. zrmanjae*

4b - A row of black pigments along free margin of each flank scale, forming a regular reticulate pattern; dark spot on scale pocket present or absent (Figs. 49b–c); eye diameter 18–24 % HL; snout stout or blunt.
..... 5

5a - 8–9½ branched anal rays; 8½ branched dorsal rays; a broad dark spot on scale pocket of each flank scale (Fig. 49b); snout blunt.
..... *S. illyricus*

5b - Usually 10½ branched anal rays; usually 9½ branched dorsal rays; no conspicuous broad dark spot on anterior half of exposed field of each flank scale (Fig. 49c); snout stout, markedly rounded.
..... *S. svallize*

Aegean and East Adriatic basins (south of Skadar-Ohrid-Drin drainage)

1a – Broad blackish stripe on body (in life); scales on upper half of flank very dark, with broad black margin; no black margin on scales of lower half of flank but broad crescentic spot on scale pockets; lateral line sometimes outlined by two series of black dots.
..... *S. keadicus*

1b – No blackish stripe on body (in life); body silvery, with narrow blackish scale margins and/or black crescentic spot on scale pockets; lateral line never outlined by two series of black dots.
..... 2

2a – Upper lip projecting beyond lower jaw (Fig. 47a); mouth subinferior.
..... 3

2b – Upper lip not or very slightly projecting (if projecting, lower jaw with well marked chin, not included in upper jaw); mouth terminal.
..... 9

3a – Distal margin of anal straight or slightly concave.
..... 4

3b – Distal margin of anal convex.
..... 6

4a - Head length 28–30 % SL; body depth 25–27 % SL; eye diameter 1.6–1.8 times in interorbital distance; 40–43 + 2–3 lateral line scales (from Mati to Aoos drainages).
..... *S.* sp. Aoos

4b – Head length 25–27 % SL; body depth 22–24 % SL; eye diameter 1.4–1.7 times in interorbital distance; 43–47 + 2–3 lateral line scales.
..... 5

5a – Length of caudal peduncle 21–22 % SL; flank scales with a black margin on posterior edge and a black crescentic spot on scale pocket (Fig. 49b) (from Acheloos to Mornos drainages).
..... *S.* sp. Evinos

5b – Length of caudal peduncle 18–21 % SL; flank scales with a black margin on posterior edge and no or very few pigments on scale pocket (Fig. 49c) (from Kalamas to Arachthos drainages).
..... *S. pamvoticus*

6a – Dorsal origin behind (rarely above) posterior extremity of pelvic base.
..... 7

6b – Dorsal origin above of in front of posterior extremity of pelvic base.
..... 8

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7a – Black pigments along free margin of each flank scale, forming a regular reticulate pattern (Figs. 49b); a dark spot on scale pocket of each flank scale; depth of caudal peduncle 1.4–1.9 times in its length (Lesbos Island).
..... *S.* cf. *cii*

7b – Free margin of flank scales faintly marked, not much contrasted against rest of scale, which is also pigmented (Fig. 49c); no dark spot on scale pocket; depth of caudal peduncle 1.7–1.9 times in its length (Evia Island).
..... *S.* sp. Evia

8a – Anal with a black mark on anterior half, formed by pigments along edge of rays, membranes hyaline; dorsal origin above posterior extremity of pelvic base (Peloponnese).
..... *S. peloponensis*

8b – Anal with blackish membranes and hyaline rays; dorsal origin above pelvic base (from Maritza to Struma drainages).
..... *S. orpheus*

9a – Head length 1.2–1.3 times body depth, 27–31 % SL; eye diameter 17–20 % HL (Lakes Prespa).
..... *S. prespensis*

9b – Head length 0.9–1.2 times body depth, 23–29 % SL; eye diameter 20–26 % HL.
..... 10

10a – Distal margin of anal convex; dorsal profile with discontinuity between head and trunk (Fig. 48); head length 25–29 % SL; usually 8½ branched anal rays (from Sperchios to Vardar drainages).
..... *S. vardarensis*

10b – Distal margin of anal straight; dorsal profile without discontinuity between head and trunk; head length 23–25 % SL; usually 9½ branched anal rays (Lake Stymphalia, northern Peloponnese).
..... *S. moreoticus*

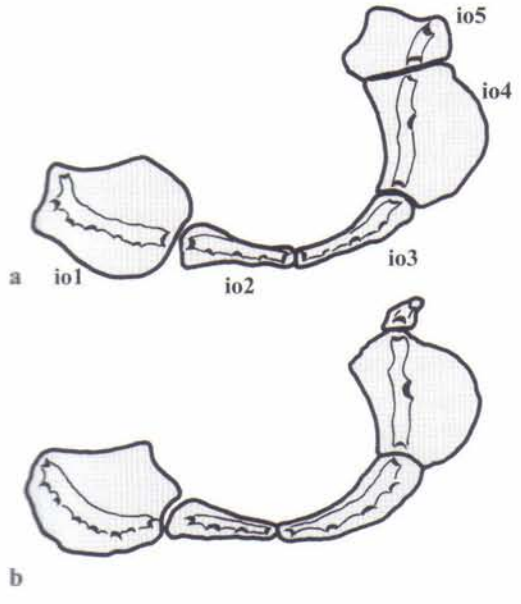

Figure 52 Infraorbital bones of *Squalius* species: **a,** infraorbital 5 very large as in *S. squalus*; **b,** infraorbital small as in *S. svallize*. **io1-5,** infraorbitals 1-5 (after Bogutskaya & Zupančič, 1999).

Squalius albus

Common name. Trasimeno chub.

Diagnosis. Distinguished from other species of *Squalius* in Apennine Peninsula by: ● body depth 19–23 % SL / ○ snout pointed / ○ 9½ branched anal rays / ○ 8½ branched dorsal rays / ○ 42–46 + 2–3 lateral line scales / ○ only very faint black pigments along free margin of flank scales above lateral line / ○ head length 24–27 % SL, greater than body depth / ○ head width 43–48 % HL / ○ mouth terminal / ○ anal and pelvic hyaline to black. Size up to at least 200 mm SL.

Distribution. Italy: Lake Trasimeno (Umbria).

Habitat. Open water.

Biology. No data.

Squalius albus

watermanⓒ

Squalius albus; Lake Trasimeno, Italy; ~140 mm SL.

Squalius aphipsi; Kuban drainage, Russia; ~120 mm SL.

Conservation status. EN B1ab(iii) + 2ab(iii)*. Still abundant in Lake Trasimeno, which is eutrophic and stocked with a wide variety of non-indigenous fish species.

Further reading. Bianco & Recchia, 1983 (systematics).

Squalius aphipsi

Common name. Kuban chub.

Diagnosis. Distinguished from other species of *Squalius* in Black Sea basin by: ♂ 9½ branched anal rays / ♂ 36–41 + 3 lateral line scales / ♂ interorbital distance 32–35 % HL / ♂ postorbital distance 45–47 % HL / ♂ eye diameter 22–26 % HL, 1.3–1.5 times in snout length / ♂ body depth 21–27 % SL / ♂ a row of black pigments along free margin of each flank scale, forming a regular reticulate pattern (Fig. 49c) / ♂ anal and pelvic orange to red. Size up to 160 mm SL.

Distribution. Kuban drainage: southern tributaries from Adagum to Laba systems.

Habitat. Piedmont and mountain streams with Mediterranean water regime, strong to moderate current, rock or gravel bottom, abundant along shores. May be restricted to very small pools during summer. Spawns in shallow riffle habitats, with strong current and stone or pebble bottom, at 10–20 cm water depth.

Biology. Males reproduce for the first time at 2 years, females often 1 year later. Spawns in April – June at temperatures above 20°C. Does not migrate long distances, but moves downstream in

Squalius aphipsi

Squalius aradensis

watermanⓒ

Squalius aradensis; Arade drainage, Portugal; ~90 mm SL.

Squalius carolitertii; Douro drainage, Portugal; ~120 mm.

winter to deeper pools, and in summer to uppermost stretches of streams. Females lay eggs in 2–3 portions during entire spawning period. Eggs are 1.9 mm in diameter, orange, and adhere to pebbles. Eggs hatch in 3 days. Larvae lack adhesive glands, are negatively phototactic and hide under stones. After start of active feeding, they drift to shallow areas. Feeds mainly on terrestrial insects, benthic invertebrates and algae.

Conservation status. LC. Abundant throughout its range.

Remarks. Placement of this species in *Squalius* is tentative. It lacks several osteological characters diagnostic for the genus and preliminary molecular data place it close to *Petroleuciscus*.

Further reading. Troitskiy & Tsunikova, 1988 (biology); Bogutskaya & Poznyak, 1994 (taxonomy).

Squalius aradensis

Common name. Arade chub.

Diagnosis. Distinguished from other species of *Squalius* in Iberian Peninsula by: ○ infraorbitals 4 and 5 very large, completely fused (Fig. 52b) / ○ 33–40 + 2 lateral line scales / ○ snout rounded / ○ mouth subterminal, upper jaw projecting / ○ head length less than body depth / ○ 2½–3 scale rows between lateral line and pelvic origin. Size up to 131 mm SL.

Distribution. Southern Portugal: Arade, Algibre and Bordeira drainages.

Habitat. Ubiquitous. Small to medium sized streams with Mediterranean water regime. Might be restricted to very small pools during summer. Spawns in shallow riffle habitats in fast-flowing water.

Biology. No data.

Conservation status. VU B2ab(iii,v).

Further reading. Coelho et al., 1998: 943 (description); Mesquita et al., 2005 (genetics).

Squalius carolitertii

Common name. Bordallo.

Diagnosis. Distinguished from other species of *Squalius* in Iberian Peninsula by: ○ 39–44 + 2–3 lateral line scales / ○ infraorbital bones narrow, width of infraorbitals 2 and 5 about 2 times width of sensory canal on same bones (Fig. 51a) / ○ snout rounded / ○ mouth subterminal / ○ head length about equal to body depth / ○ 3–4½ scale rows between lateral line and pelvic origin. Size

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Squalius cephalus; Danube, Germany; ~350 mm SL. A. Hartl

up to 210 mm SL.

Distribution. Iberian Peninsula, in Douro, Mondego, Umia, Lima, Tagus, Miño and Lérez drainages.

Habitat. From hill streams to middle stretches of rivers.

Biology. Spawns in April – June. Feeds on arthropods and fry of other fish species. Involved in the *Iberocypris alburnoides* hybrid complex.

Conservation status. LC.

Further reading. Doadrio, 1988a: 302 (description), 2001: 203 (biology); Coelho et al., 1998: 940 (morphology).

Squalius cephalus

Common name. Chub.

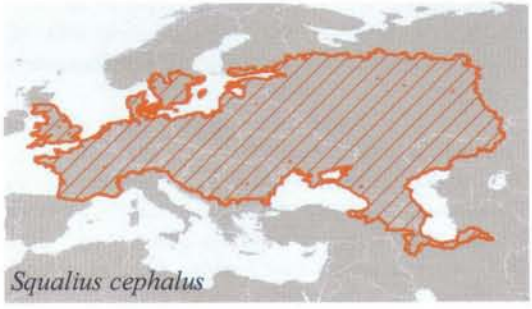
Diagnosis. Distinguished from other species of *Squalius* in France, North, Baltic, Arctic, Black and Caspian Sea basins by: ● dorsal profile with a well-marked discontinuity between head and trunk (Fig. 48b) / ● a row of black pigments along free margin of each flank scale, forming a regular reticulate pattern, with no or very few pigments on central part of scales (Fig. 49c) / ● anal and pelvic orange to red / ● 8½ (rarely 9½) branched anal rays / ● 8½ branched dorsal rays / ● 40–45 + 2–3 lateral line scales / ● mouth terminal, with well marked chin / ● tip of lower jaw not included in upper lip (Fig. 47b) / ● interorbital distance 37–42 % HL / ● postorbital distance 47–51 % HL / ● eye diameter 17–22 % HL, 1.5–2.3 times in snout length / ● body depth 22–27 % SL / ● lower jaw long, length greater than depth of operculum (Fig. 50) / ● iris whitish / ● 2,5–5,2 pharyngeal teeth / ● in stretched anal of individuals larger than about 150 mm SL, distance between tips of first and last branched rays usually greater than depth of caudal peduncle. Size up to at least 600 mm SL.

Distribution. North, Baltic, northern Black, White, Barents and Caspian Sea basins, Atlantic basin southward to Adour drainage (France), Great Britain north to 56°N, Scandinavia: southern Finland, Sweden north to about Stockholm. Mediterranean basin from Var to Hérault (possibly Aude) (France) drainages. Introduced elsewhere. Naturally absent from Italy and Adriatic basin.

Habitat. Most abundant in small rivers and large streams of barbel zone with riffles and pools. Also along shores of slow-flowing lowland rivers, even in very small mountain streams. Also in large lakes, undertaking spawning migrations to inflowing streams. Spawns in fast-flowing water above gravel bottom, rarely among submerged vegetation.

Biology. Juveniles are gregarious, adults more solitary. Lives up to 15 years, females longer than males. Males reproduce for the first time at 2–4 years, females at 4–6. Maturity is influenced by environmental factors and some individuals may mature much later. Spawns in May – August, when

Squalius carolitertii



Squalius cephalus

watermanⓒ

Squalius cf. *cii*; Lesbos Island, Greece; 96 mm SL.

Squalius cf. *cii*; Bakir drainage, Turkey; 200 mm SL.

temperature rises above 14°C. Females spawn more than once during a season. Individual females spawn with several males. Males assemble at spawning grounds and follow ripe females, often with much splashing, to shallow riffles. Females deposit the sticky eggs into the gravel. Feeding larvae and juveniles inhabit very shallow shoreline habitats. Feeds on a wide variety of aquatic and terrestrial animal and plant material. Large individuals become predominantly piscivorous. Frequently forms fertile hybrids with *Alburnus alburnus*.

Conservation status. LC.

Further reading. Hellawell, 1971 (biology); Mann, 1976 (biology); Kottelat, 2007b (systematics).

Squalius cf. *cii*

Common name. Lesbos chub.

Diagnosis. Distinguished from other species of *Squalius* around the Aegean Sea by: ❍ snout conical, with rounded tip, directed downward / ❍ mouth subterminal, uppermost point of cleft below level of lower margin of eye / ❍ usually 8½ branched anal rays / ❍ usually 8½ branched dorsal rays / ❍ 41–44 + 0–2 lateral line scales / ❍ dorsal origin behind posterior extremity of pelvic base / ❍ depth of caudal peduncle 1.4–1.9 times in its length / ❍ body slender, body depth 16–19 % SL / ❍ head length 25–30 % SL, greater than body depth / ❍ black pigments along free margin of each flank scale, forming a regular reticulate pattern / ❍ a dark spot on scale pocket of each flank scale (Fig. 49b). Size up to about 200 mm SL.

Distribution. Greece: Lesbos Island; Turkey (Anatolia): Bakir and Gediz drainages.

Habitat. Lakes and streams, sometimes restricted to isolated pools during droughts.

Biology. No data.

Conservation status. LC, but locally vulnerable (for example on Lesbos).

Further reading. Stoumboudi et al., 2006: 133 (description).

Squalius cf. cii

waterman©

Squalius illyricus; Cetina, Croatia; juvenile, ~80 mm SL.

Squalius illyricus

Common name. Illyrian chub.

Diagnosis. Distinguished from other species of *Squalius* in Western Balkans and Adriatic drainages by: ○ 46–54 total lateral line scales / ● a broad dark spot on scale pocket and a narrow series of pigments along free margin of each flank scale (Fig. 49b) (indistinct in juveniles) / ○ head depth 68–80 % HL in individuals over 90 mm SL / ○ posterior margin of anal convex or almost straight / ○ 8–9½ branched anal rays / ○ 8½ branched dorsal rays / ○ eye diameter 18–24 % HL in individuals 90–150 mm SL, 16–18 % in individuals over 250 mm SL / ○ snout blunt, dorsal profile convex / ○ lower jaw short, length less than depth of operculum / ○ 5th infraorbital bone small or absent (Fig. 52b) / ○ mouth subterminal / ○ fins yellow to black in life. Size up to 300 mm SL.

Distribution. Croatia: Cetina and Krka drainages. Earlier possibly present in Soca drainage (Slovenia, Italy), but no record since 1850.

Habitat. Streams with swift water, lakes in karstic areas.

Biology. No data.

Conservation status. NT.

Further reading. Bogutskaya & Zupančič, 1999: 517 (systematics).

Squalius keadicus

Common name. Evrotas chub.

Diagnosis. Distinguished from other species of *Squalius* in Balkan Peninsula by: ● broad blackish stripe on body (in life) / ● scales on upper half of flank very dark, with broad black margin; scales in lower half of flank without black margin but with broad crescentic spot on scale pocket / ○ 44–49 + 2–3 lateral line scales / ○ distal margin of anal straight / ○ distance between tips of first and last branched anal rays (with the fin stretched out) greater than depth of caudal peduncle. Size up to 120 mm SL.

Distribution. Greece: Evrotas drainage (Peloponnese).

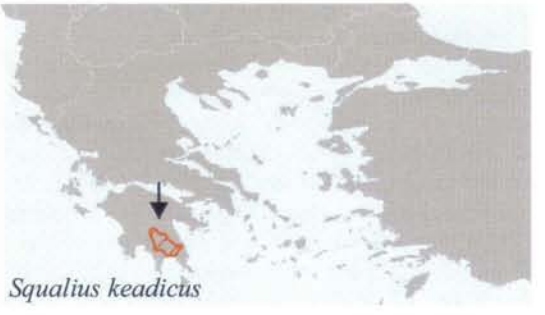
Habitat. Springs and streams with fast flow and open water.

Biology. Spawns in April – May. Eggs adhesive, 2 mm in diameter. Feeds mainly on aquatic insects.

Conservation status. EN A2ce; B1ab(i,ii,iii,iv,v) + 2ab(i,ii,iii,iv,v). During droughts, most of Evrotas basin is dried out because of water abstraction and remaining waters are severely impacted by pollution. Populations in a few large springs may be reasonably safe.

Further reading. Stephanidis, 1971a: 198 (description); Economidis, 1996 (description); Barbieri et al., 2002a: 60 (biology).

Squalius illyricus



Squalius keadicus

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Squalius keadicus; Evrotas, Greece; 110 mm SL.

Squalius laietanus; Agly, France; 158 mm SL.

Squalius laietanus

Common name. Catalan chub.

Diagnosis. Distinguished from other species of *Squalius* in western Europe by: ● mouth slightly subinferior, tip of lower jaw included in upper lip (Fig. 47a) / ○ dorsal profile with no or little-marked discontinuity between head and trunk (Fig. 48a) / ○ dorso-hypural distance falling at or behind posterior margin of eye when reported forward / ○ black pigments along free margin of each flank scale, forming a regular reticulate pattern; brown pigments on inner part of scales, denser on upper and lower extremities of exposed part, often forming faint longitudinal stripes between scale rows (Fig. 49d) / ○ 42–46 + 2–3 lateral line scales / ○ 8½ branched anal rays / ○ in stretched anal of individuals larger than about 150 mm SL, distance between tips of first and last branched rays about equal to depth of caudal peduncle. Size up to at least 210 mm SL.

Distribution. Spain: Ebro and Llobregat drainages. France: Tech and Agly drainages, possibly also Aude (Languedoc-Roussillon); possible introgression with *S. cephalus* in southern Garonne tributaries and Adour drainage.

Habitat. Streams with flowing, clear water.

Biology. No data.

Conservation status. LC.

Further reading. Sanjur et al., 2003 (genetics); Doadrio et al., 2007 (description).

Squalius lucumonis

Common name. Toscana stream chub.

Diagnosis. Distinguished from other species of *Squalius* in Apennine Peninsula by: ● 7½ branched dorsal rays / ○ posterior margin of anal convex or almost straight / ○ 8½ branched anal rays / ○ 37–40 + 3 lateral line scales / ○ a row of black pigments along free margin of each flank scale, forming a regular reticulate pattern (Fig. 49c). Size up to 160 mm SL.

Distribution. Italy: Serchio, Ombrone, Arno and Tevere drainages (Tyrrhenian slope).

Habitat. Small to medium sized premontane

Squalius laietanus

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Squalius lucumonis; Ombrone drainage, Italy; ~100 mm SL.

Squalius malacitanus; vicinity of Malaga, Spain; ~100 mm SL. A. Hartl

streams with Mediterranean water regime. May be restricted to very small pools during summer. Spawns in shallow riffle habitats in fast-flowing water.

Biology. No data.

Conservation status. EN B2ab(i,ii,iii,iv), due to habitat alterations and water abstraction.

Further reading. Bianco, 1983: 82 (description).

Squalius malacitanus

Common name. Malaga chub.

Diagnosis. Distinguished from other species of *Squalius* in Iberian Peninsula by: ● 37–41 + 2 lateral line scales / ● infraorbital bones broad, width of infraorbitals 2 and 5 about 4–5 times width of sensory canal on same bones (Fig. 51b) / ● a black crescentic mark on scale pocket of each flank scale (Fig. 49b) / ● depth of caudal peduncle usually 2.4–2.8 times in its length / ● head length about equal to or slightly smaller than body depth / ● mouth terminal / ● snout shorter or equal to eye diameter / ● 4 scale rows between lateral line and pelvic origin. Size up to at least 80 mm SL.

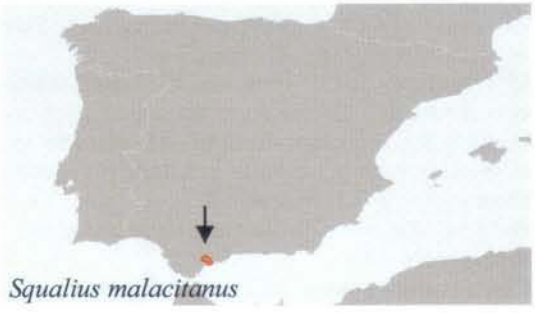
Distribution. Guadalmina, Guadaiza and Guadiaro drainages (near Malaga, Spain).

Habitat. Streams with clear water, gravel bottom, in stretches with slow current.

Biology. No data.

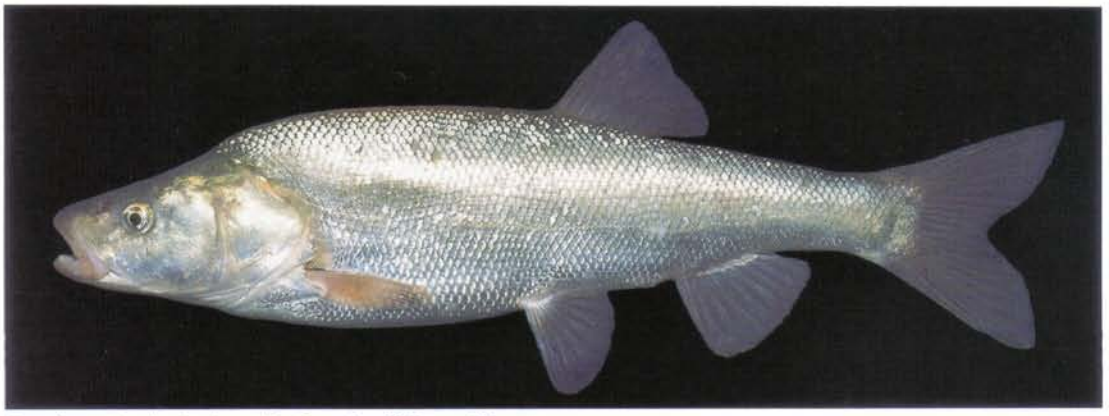
Conservation status. EN B1ab(ii,iii,v) + 2ab(ii, iii,v). Threatened by water abstraction for golf courses.

Squalius lucumonis

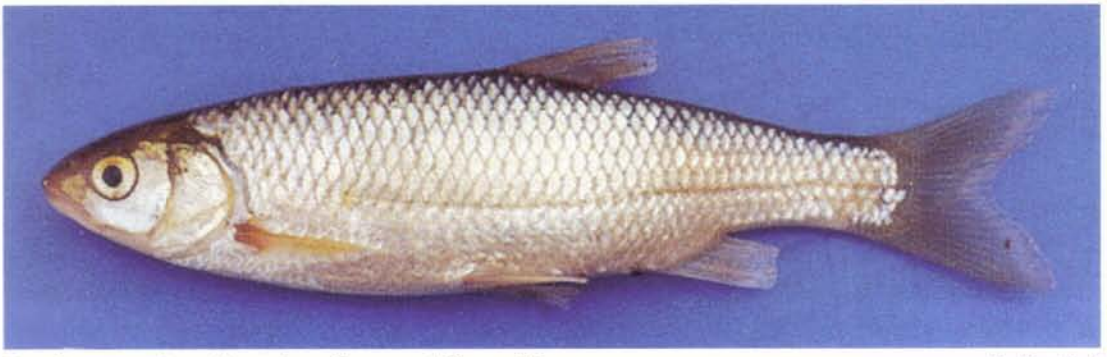


Squalius malacitanus

watermanⓒ



Squalius microlepis; Imotski, Croatia; 287 mm SL.



Squalius moreoticus; Vourraikos, Greece; ~150 mm SL. R. Barbieri

Further reading. Doadrio & Carmona, 2006: 203 (systematics).

Squalius microlepis

Common name. Imotski masnica.

Diagnosis. Distinguished from other species of *Squalius* in Western Balkans and Adriatic basin by: ○ 67–75 total lateral line scales / ○ ½13–15/ 1/5–6 scales in transverse row from dorsal to pelvic origins / ○ 24–26 circumpeduncular scale rows / ○ mouth terminal / ○ 8½ branched dorsal rays / ○ 8½ branched anal rays. Size up to 340 mm SL.

Distribution. Prološko and Ričice basins near Imotski, Matica drainage near Vrgorac (Croatia); Tihaljina and possibly Trebižat (a Neretva tributary) drainages (Bosnia-Herzegovina).

Habitat. Lakes and still water. Spawns along lake shores.

Biology. Adults are open water predators in lakes, feeding on juveniles fishes.

Conservation status. EN B2ab(ii,iii), threatened by overfishing. Extirpated in Neretva drainage.

Further reading. Bănărescu & Herzig-Straschil, 1998: 417 (description); Karaman, 1929: 159 (systematics, biology).

Squalius moreoticus

Common name. Stymphalia chub.

Diagnosis. Distinguished from other species of *Squalius* in Balkan Peninsula by: ○ head length 0.9–1.1 times body depth, 23–25 % SL / ○ upper

Squalius microlepis

Squalius moreoticus

watermanⓒ

Squalius orpheus; Maritza, Greece; 118 mm SL.

Squalius orpheus; Maritza drainage, Greece; ~130 mm SL.

lip not or very slightly projecting / ○ lower jaw with well marked chin, not included in upper jaw / ○ mouth terminal / ○ eye diameter 22–25 % HL / ○ 41–44 + 2–3 lateral line scales / ○ usually 9½ branched anal rays / ○ 8½ branched dorsal rays / ○ distal margin of anal straight / ○ distance between tips of first and last branched anal rays (with the fin stretched out) greater than depth of caudal peduncle. Size up to about 210 mm SL.

Distribution. Greece: Lake Stymphalia and Vouraikos drainage (Peloponnese); possibly present in other drainages of northern Peloponnese.

Habitat. Lacustrine and streams with flowing, clear water.

Biology. Spawns for the first time at 1 year. Spawns in April – May. Feeds on a variety of plant and animal food.

Conservation status. EN B1ab(ii,iii,v) + 2abc(ii, iii,v). Lake Stymphalia was dry in 1998; not observed in 2002, but *Squalius* larvae were present in 2004.

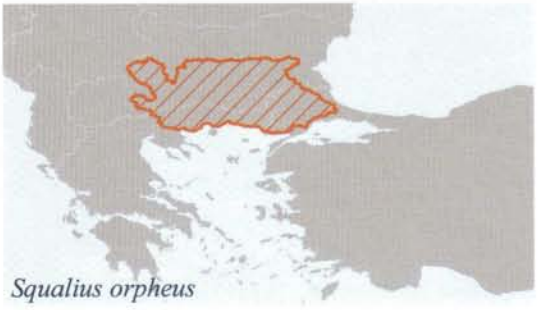
Remarks. See under *S. peloponensis*.

Further reading. Stephanidis, 1971a: 197 (description); Doadrio & Carmona, 1998 (genetics); Zardoya et al., 1999 (genetics); Barbieri et al., 2002a: 56 (biology; as *L. cephalus*, in part).

Squalius orpheus

Common name. Maritza chub.

Diagnosis. Distinguished from other species of *Squalius* in Balkan Peninsula by: ● dorsal origin above pelvic base / ● dorso-hypural distance reaching between eye and nostril when reported forward from dorsal origin / ○ free margin of flank scales faintly marked, not much contrasted against rest of scale, which is also pigmented; scale pock-



Squalius orpheus

Squalius pamvotícus

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Squalius pamvoticus; Kalamas drainage, Greece; 100 mm SL.

et dark brown / ● anal with blackish membranes and hyaline rays / ● head length equal to or slightly greater than body depth / ● mouth subterminal, upper lip conspicuously projecting beyond lower jaw, sometimes including tip of lower jaw (Fig. 47a) / ● 44–46 + 2 lateral line scales / ● 8½ branched anal rays / ● 8½ branched dorsal rays / ● posterior margin of anal convex / ● in stretched anal of individuals larger than about 100 mm SL, distance between tips of first and last branched rays (with the fin stretched out) 1.0–1.3 times depth of caudal peduncle / ● head length 26–29 % SL. Size up to 145 mm SL, probably larger.

Distribution. From Maritza to Struma drainages (Greece, Bulgaria, Turkey).

Habitat. Streams and rivers, stretches with moderate current.

Biology. Omnivorous; feeds mainly on insects and aquatic invertebrates. Spawns in April – June in shallow areas with gravel bottom.

Conservation status. LC. Globally reasonably safe as there is a number of populations, but some populations threatened by water abstraction in dry season.

Further reading. Kottelat & Economidis, 2006: 182 (description).

Squalius pamvoticus

Common name. Pamvotis chub.

Diagnosis. Distinguished from other species of *Squalius* in Balkan Peninsula by: ● upper lip projecting beyond lower jaw / ● mouth subinferior / ● distal margin of anal straight / ● distance between tips of first and last branched anal rays (with the fin stretched out) less than depth of caudal peduncle / ● head length 26–27 % SL / ● body depth 22–25 % SL / ● eye diameter 1.4–1.7 times in interorbital distance / ● 43–47 + 2–3 lateral line scales / ● length of caudal peduncle 18–21 % SL / ● scales of dorsal half of flank with a black margin on posterior edge and no or very few pigment on scale pocket (Fig. 49c) / ● usually 9½ branched anal rays / ● usually 8½ branched dorsal rays. Size up to about 300 mm SL.

Distribution. Greece: Kalamas, Acheron, Louros and Arachthos drainages; Lake Pamvotis.

Habitat. Streams with flowing, clear water.

Biology. No data.

Conservation status. LC.

Remarks. See under *S. peloponensis*.

Further reading. Steindachner, 1896: 184 (description; as *S. cephalus* var. *albus*); Doadrio & Carmona, 1998 (genetics); Durand et al., 2000 (genetics).

Squalius peloponensis

Common name. Peloponnese chub.

Diagnosis. Distinguished from other species of *Squalius* in Balkan Peninsula by: ● anal with a black mark on anterior half, formed by pigments along edge of rays, membranes hyaline / ● head length about equal to body depth / ● mouth subinferior, upper lip conspicuously projecting beyond lower jaw / ● 40–44 + 2–3 lateral line scales / ● 8–9½ branched anal rays / ● 8½ branched dorsal rays / ● posterior margin of anal slightly convex / ● distance between tips of first and last branched anal rays (with the fin stretched out) greater than depth of caudal peduncle / ● head length 24–27 % SL / ● dorsal origin above posterior extremity of base of pelvic / ● dorso-hypural distance reaching middle of eye when reported forward from dorsal origin. Size up to about 300 mm SL.

Distribution. Greece: Peloponnese (except Evrotas and Lake Stymphalia).

Squalius peloponensis

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Squalius peloponensis; Alfios drainage, Greece; 127 mm SL.

Squalius prespensis; Lake Prespa, Greece; 163 mm SL.

Habitat. Streams to rivers, with moderate to swift current.
Biology. Spawns for the first time at 2 years. Spawns in March – April in lowlands and May in upper reaches. Spawns adhesive eggs 1.8 mm in diameter in gravel. Feeds on a variety of plant and animal food.
Conservation status. LC. Globally reasonably safe as there is a number of populations, but several populations threatened by water abstraction in the dry season.
Remarks. *Squalius* from the drainages of western Peloponnese and western Greece have been reported as *S. peloponensis*, *S. cephalus*, or *S. svallize*. In fact this is an heterogeneous assemblage and many populations can be distinguished by morphological and/or molecular characters. This is presently being investigated. We organise these populations into five groups that we tentatively recognise as distinct species. Names are available for three of them (*S. peloponensis*, *S. pamvoticus*, *S. moreoticus*). The other two species are not yet named (*S.* sp. Aoos, *S.* sp. Evinos).
Further reading. Stephanidis, 1971a: 193 (description); Doadrio & Carmona, 1998 (genetics); Barbieri et al., 2002a: 60 (biology; as *S. cephalus*, in part.).

Squalius prespensis

Common name. Prespa chub.
Diagnosis. Distinguished from other species of *Squalius* in Balkan Peninsula by: ● head length 1.2–1.3 times body depth, 27–31 % SL / ○ upper lip not projecting / ○ mouth terminal / ○ eye diameter 17–20 % HL / ○ 41–44 + 2 lateral line scales / ○ body depth 21–24 % SL / ○ 8–9½

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Squalius pyrenaicus; Guadiana, Spain; ~90 mm SL.

branched anal rays / O 8½ branched dorsal rays / O distal margin of anal convex / O distance between tips of first and last branched anal rays (with the fin stretched out) 1.2–1.3 times depth of caudal peduncle / O fins greyish to blackish. Size up to about 250 mm SL.

Distribution. Lakes Prespa basin (Greece, Macedonia, Albania).

Habitat. Lacustrine, along shores.

Biology. Spawns in May.

Conservation status. VU D2*.

Further reading. Karaman, 1924: 67 (description); Stephanidis, 1971a: 191 (characters); Doadrio & Carmona, 1998 (genetics).

Squalius pyrenaicus

Common name. Cacho.

Diagnosis. Distinguished from other species of *Squalius* in Iberian Peninsula by: O 37–42 + 2–3 lateral line scales / O infraorbital bones broad, width of infraorbitals 2 and 5 about 4–5 times width of sensory canal on same bones (Fig. 51b) / O a black crescentic mark on scale pocket of each flank scale (Fig. 49b) (often indistinct in life) / O head length about equal to body depth / O caudal peduncle depth usually 2.0–2.6 times in its length / O mouth terminal / O snout pointed / O 3–5 scale rows between lateral line and pelvic origin. Size up to 260 mm SL.

Distribution. Iberian Peninsula, from Tagus and lower Ebro drainages southward; missing in Mediterranean slope between Mijares and Vinalopo drainages (present in upper Jucar) and between Guadaiza and Guadiaro drainages (near Malaga). Possibly introduced in Ebro drainage.

Habitat. Ubiquitous. Small to medium sized streams with Mediterranean water regime. May be restricted to very small pools during summer. Spawns in shallow riffle habitats in fast-flowing water.

Biology. Feeds mainly on small arthropods. Spawns in April – July, on stone to gravel bottom. Involved in the *Iberocypris alburnoides* hybrid complex.

Conservation status. NT.

Further reading. Doadrio, 1988a (systematics),

Lake Prespa near Psarades, Greece; habitat of *Squalius prespensis*, *Barbus prespensis*, *Chondrostoma prespense*, *Alburnus belvica*, *Alburnoides prespensis*, *Pelasgus prespensis*, *Rutilus prespensis* and *Cobitis meridionalis*.

watermanⓒ

Squalius squalus; Lake Lugano basin, Switzerland; 127 mm SL.

Squalius squalus; Lake Garda, Italy; ~150 mm SL.

2001: 203 (biology, conservation status); Coelho et al., 1998: 940 (morphology); Doadrio & Carmona, 2006 (systematics).

Squalius squalus

Common name. Cavedano chub.

Diagnosis. Distinguished from other species of *Squalius* in Apennine Peninsula by: ○ body depth 22–27 % SL / ○ 8–10½ (usually 9½) branched anal rays / ○ 8½ branched dorsal rays / ○ 40–45 + 2–3 lateral line scales / ○ posterior margin of anal convex or almost straight / ○ a row of black pigments along free margin of each flank scale, forming a regular reticulate pattern / ○ head length 25–28 % SL, greater than body depth / ○ head width 43–47 % HL / ○ mouth terminal / ○ anal and pelvic hyaline to black.

Distinguished from other species of *Squalius* in eastern Adriatic drainages by: ○ a row of black pigments along free margin of each flank scale, forming a regular reticulate pattern / ● 5th infraorbital bone very large (Fig. 52a) / ○ 40–45 + 2–3 lateral line scales.

Distinguished from *S. cephalus* (which often occurs in adjacent drainages) by: interorbital distance 34–39 % HL (vs. 37–42); usually 9½ branched anal rays (vs. usually 8½); and anal and pelvic hyaline to black (vs. orange to red). Size up to at least 600 mm SL.

Distribution. Ligurian and Tyrrhenian Sea basins, from Genova to southernmost Italy, Ionian Sea basin in southern Italy (Sini and Basento drainages), Adriatic basin from Ofanto drainage (southern Italy) to Skadar and Ohrid basins.

Habitat. Most abundant in small rivers and streams with riffles and pools. May be restricted to very small pools during summer. Spawns in shallow riffle habitats in fast-flowing water. Also along shores of slowly flowing lowland rivers, even in very small mountain streams. Also in large lakes, undertaking spawning migrations to inflowing streams or spawning in very shallow water, over stones close to surf zone.

Biology. Juveniles gregarious, adults more solitary. Lives up to 15 years. Males reproduce for the first time at 1–3 years, females at 3–5. Spawns in April – July, when temperature rises above 14°C. Females spawn more than once during a season.

watermanⓒ

Squalius svallize; Neretva delta, Croatia; ~180 mm SL.

Individual females spawn with several males. Males assemble at spawning grounds and follow ripe females, often with much splashing, to shallow riffles or lake shores. Females deposit the sticky eggs into excavations made in gravel. Feeding larvae and juveniles inhabit very shallow shoreline habitats. Feeds on a wide variety of aquatic and terrestrial animal and plant material. Large individuals become predominantly piscivorous. Frequently forms hybrids with *Alburnus arborella* and *A. albidus*.

Conservation status. LC.

Remarks. Note that correct spelling of species name is '*squalus*' without 'i'. Populations from Savuto drainage (Calabria, southern Italy) are distinguished by having 9½ branched dorsal rays. They have been treated as, and indeed could be, a distinct taxon. If this is confirmed, the name *S. ruffoi* is available for it. Populations from the eastern drainages of the Adriatic basin probably represent more than one species.

Further reading. Bianco & Recchia, 1983: 16 (diagnosis; as *Leuciscus cephalus cabeda*); Gandolfi et al., 1991: 139 (biology; as *L. cephalus*); Kottelat, 2007b (systematics).

Squalius svallize

Common name. Neretva chub.

Diagnosis. Distinguished from other species of *Squalius* in Western Balkans and Adriatic basin by: O 44–51 total lateral line scales / O a row of black pigments along free margin of each flank scale, forming a regular reticulate pattern, and no conspicuous broad dark spot on anterior half of exposed field of each flank scale (Fig. 49c) / O 9–10½ (usually 10½) branched anal rays / O 8–9½ (usually 9½) branched dorsal rays / O eye diameter 19–23 % HL / O head shallow, conical / O snout stout, markedly rounded / O lower jaw short, length less than depth of operculum / O mouth subterminal. Size up to 200 mm SL.

Distribution. Neretva, Trebišnjica and Ljuta drainages (Croatia, Bosnia-Herzegovina).

Habitat. Streams with swift water, lakes in karstic areas. Enters subterranean waters.

Biology. Spawns in April – June.

Conservation. VU D2. Abundant in middle Neretva drainage.

Further reading. Bianco & Knežević, 1987: 51 (description); Bogutskaya & Zupančič, 1999: 520 (systematics).

Squalius tenellus

Common name. Livno masnica.

Diagnosis. Distinguished from other species of *Squalius* in Western Balkans and Adriatic basin by: ● 76–85 total lateral line scales / ● ½15–17/1/6–7 scales in transverse row from dorsal to pelvic origins / ● 28–32 circumpeduncular scale rows / O mouth terminal. Size up to 400 mm SL.

Distribution. River Cetina, also in karstic streams in Livanjsko polje, Lakes Buško and Mandečko near Livno. Possibly introduced to Lake Blidinje (Bosnia-Herzegovina) more than 100 years ago.

Habitat. Slow-flowing and still waters and lakes. Enters subterranean waters during winter or droughts.

Biology. Spawns in April – June. In lakes, adults prey on small fishes.

Conservation status. EN B1ab(ii,iii) + 2ab(ii,iii),

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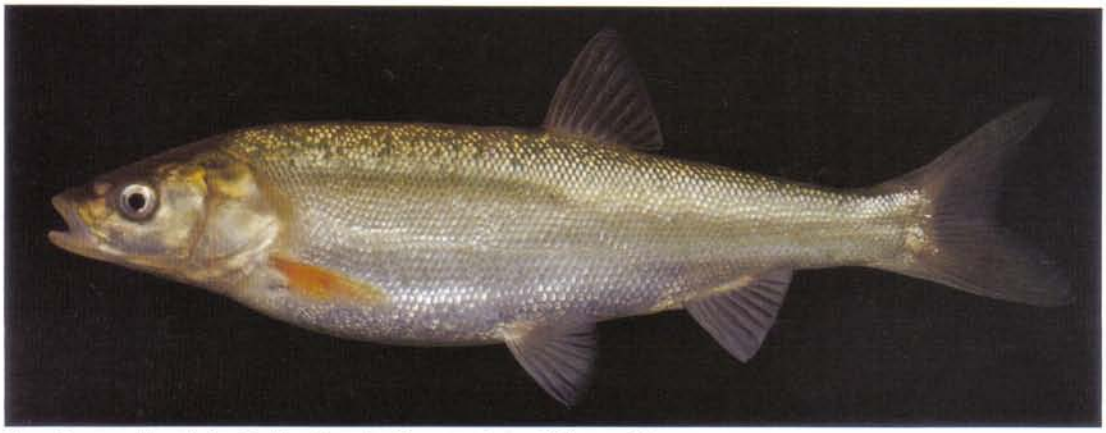

Squalius tenellus; Lake Buško, Bosnia-Herzegovina; ~260 mm SL.

Squalius torgalensis; Mina drainage, Protugal; ~80 mm SL.

due to small range, water abstraction and pollution. Sharply declined during 20th century due to habitat loss and pollution.

Further reading. Vuković & Ivanović, 1971: 151 (habitat); Aganović et al., 1974: 1–6 (biology; as *Leuciscus turskyi*); Bănărescu & Herzig-Straschil, 1998: 419 (description).

Squalius torgalensis

Common name. Torgal chub.

Diagnosis. Distinguished from other species of *Squalius* in Iberian Peninsula by: ○ infraorbitals 4 and 5 very large, often fused (Fig. 52b) / ○ 34–39 + 2 lateral line scales / ○ snout pointed / ○ mouth terminal / ○ head length greater than body depth / ○ a black dot on each scale / ● 1½–2½ scale rows between lateral line and pelvic origin. Size up to 118 mm SL.

Distribution. Southern Portugal: Torgal drainage.

Habitat. Ubiquitous. Small to medium sized streams. May be restricted to very small pools during summer. Spawns in shallow riffle habitats in fast-flowing water.

Biology. No data.

Squalius tenellus

Squalius torgalensis

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Squalius valentinus; Algar drainage, Spain; 120 mm SL.

Squalius vardarensis; Vardar, Greece; 144 mm SL.

Conservation status. EN B1ab(ii,iii) + 2ab(ii,iii).
Further reading. Coelho et al., 1998: 939 (description).

Squalius valentinus

Common name. Valencia chub.
Diagnosis. Distinguished from other species of *Squalius* in Iberian Peninsula by: ● 33–37+ 2 lateral line scales / ● infraorbital bones broad, width of infraorbitals 2 and 5 about 4–5 times width of sensory canal on same bones (Fig. 51b) / ● a black crescentic mark on scale pocket of each flank scale (Fig. 49b) / ● head length about equal to body depth / ● mouth terminal / ● 4 scale rows between lateral line and pelvic origin. Size up to at least 130 mm SL.
Distribution. Mediterranean slope of Spain, from Mijares to Vinalopo drainages; lower part of Jucar drainage.
Habitat. Streams with clear water, gravel bottom, in stretches with and slow current.
Biology. No data.
Conservation status. VU B1ab(ii,iii,v). Threatened by water abstraction for agriculture, construction of reservoirs and introduced species.
Further reading. Doadrio & Carmona, 2006: 207 (systematics).

Squalius vardarensis

Common name. Vardar chub.
Diagnosis. Distinguished from other species of *Squalius* in Balkan Peninsula by: ● upper lip not projecting / ● mouth terminal / ● head length 1.0–1.2 times body depth, 25–29 % SL / ● eye diameter 20–26 % HL / ● 41–44 + 2–3 lateral line scales / ● usually 8½ branched anal rays / ● 8½ branched dorsal rays / ● distance between tips of first and last branched anal rays (with the fin

Squalius valentinus

Squalius zrmanjae; Zrmanja, Croatia; 150 mm SL.

stretched out) about equal to or slightly greater than depth of caudal peduncle / O distal margin of anal convex. Size up to about 160 mm SL.
Distribution. From Sperchios to Vardar drainages (Greece, Macedonia).
Habitat. Streams with flowing, clear water.
Biology. No data.
Conservation status. LC.
Further reading. Durand et al., 2000 (genetics); Kottelat & Economidis, 2006 (diagnosis).

Squalius zrmanjae

Common name. Zrmanja chub.
Diagnosis. Distinguished from other species of *Squalius* in Western Balkans and Adriatic basin by: O 44–49 total lateral line scales / ● a conspicuous dark triangular spot on scale pocket of each flank scale above lateral line (Fig. 49a), pigments usually absent along free margin / ● eye diameter 24–28 % HL, slightly less than snout length / O 5th infraorbital bone small or absent (Fig. 52b) / O 9½ branched anal rays / O usually 8½ branched dorsal rays / O head shallow, conical / O snout elongate, dorsal profile slightly rounded / O lower jaw short, length less than depth of operculum / O mouth subterminal. Size up to 280 mm SL.
Distribution. Croatia: Zrmanja and Krka drainages. Introduced in Ričica polje with water diverted from Zrmanja for a hydroelectric plant.
Habitat. Streams with swift water, lakes in karstic areas. In Zrmanja restricted to lower, almost still part.
Biology. No data.
Conservation status. NT.
Further reading. Bogutskaya & Zupančič, 1999: 511 (systematics).

Squalius sp. Aoos

Common name. Aoos chub.
Diagnosis. Distinguished from other species of *Squalius* in Balkan Peninsula by: O upper lip projecting beyond lower jaw / O mouth subinferior / O distal margin of anal straight / O distance between tips of first and last branched anal rays (with the fin stretched out) less than depth of caudal peduncle / O head length 28–30 % SL / O body depth 25–27 % SL / O eye diameter 1.6–1.8 times in interorbital distance / O 40–43 + 2–3 lateral line scales / O usually 8½ branched anal rays / O 8½ branched dorsal rays / O flank scales with a black margin on posterior edge and no or very few pigment on scale pocket (Fig. 49c). Size up to about 140 mm SL.
Distribution. From Mati to Aoos drainages (Albania and Greece).
Habitat. Streams with flowing, clear water.

Squalius vardarensis

Squalius zrmanjae

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Squalius sp. Aoos; Aoos drainage, Greece; 107 mm SL.

Squalius sp. Evia; Evia Island, Greece; 162 mm SL.

Biology. No data.
Remarks. See under *S. peloponensis*. A group of populations sharing morphological and molecular characters; apparently one or several unnamed species whose status is presently being investigated.
Conservation status. NT.
Further reading. Doadrio & Carmona, 1998 (genetics); Durand et al., 2000 (genetics).

Squalius sp. Evia

Common name. Evia chub.
Diagnosis. Distinguished from other species of *Squalius* in Balkan Peninsula by: ❍ free margin of flank scales faintly marked, not much contrasted against rest of scale, which is also pigmented / ❍ no dark spot on scale pocket / ❍ dorsal origin above or behind base of last pelvic ray / ❍ dorsohypural distance reaching to about middle of eye when reported forward from dorsal origin / ❍ head length 26–28 % SL, greater than body depth / ❍ mouth subinferior, upper lip conspicuously projecting beyond lower jaw, sometimes including tip of upper jaw (Fig. 47a) / ❍ 43–46 + 2–3 lateral line scales / ❍ 8½ branched anal rays / ❍ 8½ branched dorsal rays / ❍ posterior margin of anal convex / ❍ distance between tips of first and last branched anal rays (with the fin stretched out) greater than depth of caudal peduncle / ❍ depth of caudal peduncle 1.7–1.9 times in its length. Size up to about 300 mm SL.
Distribution. Greece: lower stretch of Manikiotiko stream on eastern slope of Evia (Euboea) Island.
Habitat. Stream on gravel bottom, flow usually interrupted in summer when only a few pools may subsist.

Squalius sp. Aos

Squalius sp. Evia

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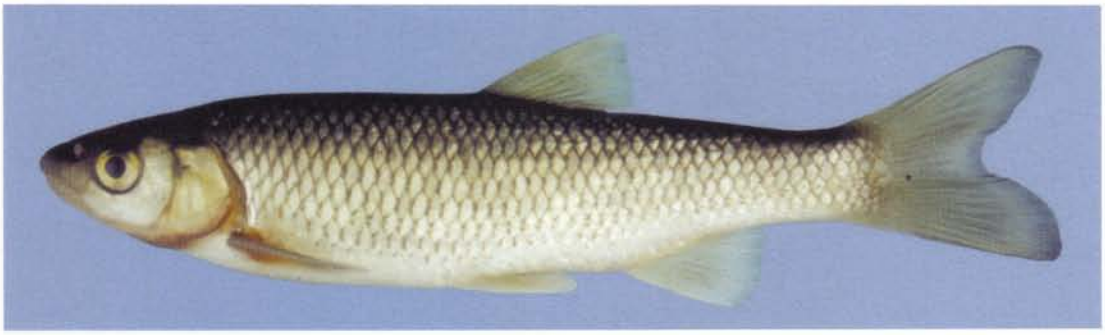

Squalius sp. Evinos; Evinos drainage, Greece; 136 mm SL.

Biology. No data. In June, individuals over 110 mm SL had nuptial tubercles.
Conservation status. CR B1ab(ii,iii) + 2ab(ii,iii). In dry years, the stream dries completely and the species survives only in a few pools.
Remarks. The status of this population is not clear. Some morphological and molecular data suggest it is a distinct species, but this is conflicting with other molecular data.
Further reading. Doadrio & Carmona, 1998 (genetics).

Squalius sp. Evinos

Common name. Acheloos chub.
Diagnosis. Distinguished from other species of *Squalius* in Balkan Peninsula by: ○ upper lip projecting beyond lower jaw / ○ mouth subinferior / ○ distal margin of anal straight / ○ distance between tips of first and last branched anal rays (with the fin stretched out) less than depth of caudal peduncle / ○ head length 25–27 % SL / ○ body depth 22–24 % SL / ○ eye diameter 1.4–1.6 times in interorbital distance / ○ 43–44 + 2–3 lateral line scales / ○ length of caudal peduncle 21–22 % SL / ○ flank scales with a black margin on posterior edge and a black spot on scale pocket (Fig. 49b) / ○ 8–9½ branched anal rays / ○ 8½ branched dorsal rays. Size up to about 200 mm SL.
Distribution. Greece: Acheloos, Evinos and Mornos drainages.
Habitat. Streams with clear water; lakes, in areas close to estuaries of tributary streams.
Biology. Spawns for the first time at 2–3 years. Spawns in April – June; lacustrine populations migrate to streams for spawning. Fractional spawner. Lays adhesive eggs on gravel bottom. Eggs hatch in 3 days.
Conservation status. LC**.
Remarks. See under *S. peloponensis*. A group of populations sharing morphological and molecular characters; apparently an unnamed species whose status is presently being investigated.
Further reading. Economou et al., 1991 (ontogeny, as *Leuciscus cephalus*), 1994a: 20 (reproduction, larvae); Doadrio & Carmona, 1998 (genetics); Durand et al., 2000 (genetics).

Squalius sp. Evinos

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Telestes

Species of *Telestes* are characterised by the absence of a scaleless midventral keel in front of the anus, a complete lateral line, a terminal or subterminal mouth, the dorsal origin behind pelvic base, 7–10½ branched anal rays and 7–8½ branched dorsal rays. A conspicuous black midlateral stripe and a black line along the lateral line are the most striking characters of *Telestes*. While this pattern is usually distinct in preserved individuals, it is less obvious in life. The stripe is more prominent in breeding individuals than in juveniles or adults outside the spawning season.

Species of *Telestes* inhabit habitats ranging from hill streams and mountain lakes to foothill streams. Most occur in the eastern Adriatic drainage and several have restricted ranges and vanished in several localities during the last decades. Most species were earlier included in *Leuciscus*, but congruent molecular and morphological data indicate that *Telestes* is more closely related to *Chondrostoma*, *Achondrostoma*, *Pseudochondrostoma*, *Parachondrostoma*, *Protochondrostoma*, *Iberochondrostoma*, and *Phoxinellus*. Three species earlier referred to *Phoxinellus* have recently been transferred to *Telestes*. The systematics of *Telestes* is still not yet resolved and several species might be confused under *T. souffia*.

Keys to species of *Telestes*

1a – Scales normally developed, overlapping. 2

1b – Scales very thin, not overlapping (Fig. 53). 9

2a – 67–79 total lateral line scales. 3

2b – 43–66 total lateral line scales. 4

3a – 8–9 gill rakers; depth of caudal peduncle 2.0–2.2 times in its length (Croatia: Čikola drainage). ..... *T. turskyi*

3b – 6–7 gill rakers; depth of caudal peduncle 2.1–2.7 times in its length (Croatia: Stajnička Jaruga and Zagorska Drežnica). ..... *T. polylepis*

4a – Usually 7½ (rarely 8½) branched anal rays; midlateral stripe weakly marked, almost each scale of side with a dark grey spot, often forming small stripes (Greece: Kifissos drainage). ..... *T. beoticus*

4b – 8–10½ branched anal rays; conspicuous black midlateral stripe and conspicuous black line along lateral line (when preserved; in life, often broad gold-orange stripe; lateral line yellow, bordered on each side by a narrow black line). 5

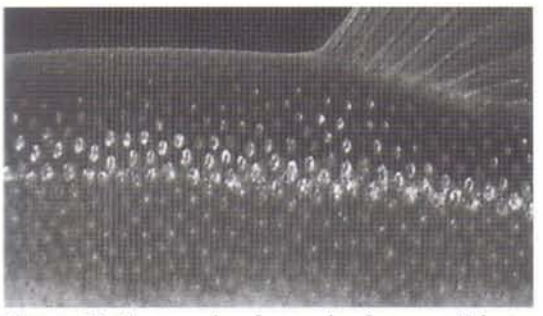

Figure 53 Non-overlapping scales in some *Telestes* species.

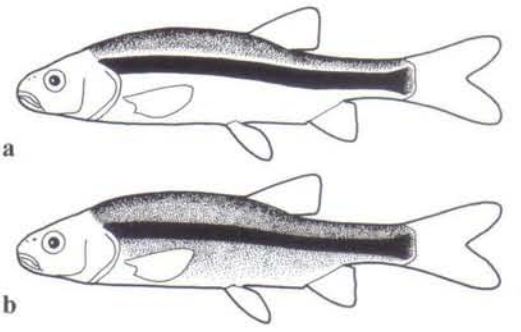

Figure 54 Dark stripe in *Telestes* species: **a,** separated from dark area of back; **b,** within dark area of back and flank.

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5a – Tip of snout pointed, snout not projecting beyond tip of upper lip (Montenegro).
..... *T. montenigrinus*

5b – Tip of snout rounded or blunt, snout projecting beyond tip of upper lip.
..... 6

6a – Pharyngeal teeth in one row (5–5) (western Greece).
..... *T. pleurobipunctatus*

6b – Pharyngeal teeth in two rows (usually 2,5–5,2).
..... 7

7a – 58–66 + 3 lateral line scales (Cetina drainage, Croatia).
..... *T. ukliva*

7b – 43–57 + 2–3 lateral line scales.
..... 8

8a – 8½ branched anal rays; 43–49 + 2–3 lateral line scales; 3½ scale rows between lateral line and pelvic origin; eye diameter 3.3–3.6 times in HL (Po and adjacent drainages in Italy, France, Switzerland and Slovenia).
..... *T. muticellus*

8b – Usually 9½ branched anal rays; usually 50–57 + 2–3 lateral line scales; 4½–5 scale rows between lateral line and pelvic origin; eye diameter 4.0–4.6 times in HL (Rhône, upper Rhine, upper Danube, Soca and adjacent drainages).
..... *T. souffia*

9a – Narrow dark stripe from opercle to caudal base along lateral line, separated from main dark pigmented area of back (Fig. 54a); 7–8½ branched dorsal rays; 8½ branched anal rays (Nevesinje, Gacko, Cernica and Dabar poljes, Bosnia-Herzegovina);.
..... *T. metohiensis*

9b – Broad dark stripe from eye to caudal peduncle, within main pigmented area of back and flank (Fig. 54b); lateral line marked by small dark dots; usually 7½ branched dorsal rays; 7–8½ branched anal rays.
..... 10

10a – Usually 8½ branched anal rays; lateral line reaching to above anal, rarely shorter, with 51–70 pored scales; body thick, almost cylindrical (Lika-Jadova, Ričica and Otuca drainages, Croatia).
..... *T. croaticus*

10b – 7½ branched anal rays; lateral line interrupted, with 23–37 pored scales, ending between pectoral and anal; body markedly compressed (Krbava polje, Croatia).
..... *T. fontinalis*

Telestes beoticus

Common name. Beotian riffle dace.

Diagnosis. Distinguished from other species of *Telestes* by: ● midlateral stripe weakly marked, almost each scale of side with a dark grey spot, often forming small stripes / ○ caudal peduncle deep, depth 1.6–1.9 times in its length / ○ snout blunt / ○ 50–55 + 2–3 lateral line scales / ○ 7–8½ branched anal rays. Size up to about 120 mm SL.

Distribution. Greece: Kifissos and Assopos drainages.

Habitat. In streams, prefers cool and swift waters associated with springs.

Biology. Spawns in January – March.

Conservation status. EN B1ab(i,ii,iii,iv,v). Extirpated from Assopos. During droughts survives in only a few springs.

Further reading. Stephanidis, 1939b: 57 (description), 1974: 241 (description).

Telestes croaticus

Common name. Croatian pijor.

Diagnosis. Distinguished from other species of *Telestes* by: ○ scales very thin, not overlapping / ○ broad dark midlateral stripe from eye to end of caudal peduncle within pigmented area on back and flank (Fig. 54b) / ○ 7½ branched dorsal rays / ● usually 8½ (rarely 7½) branched anal rays / ● posterior margin of dorsal and anal markedly rounded / ○ snout stout, markedly rounded, mouth almost or clearly subterminal / ○ skin not thickened, scales clearly visible, covering whole body, often narrowly to widely separated, especially in pre-pelvic area / ○ lateral line usually ending

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Telestes beoticus; Kifissos drainage, Greece; 92 mm SL.

Telestes coaticus; Jadova polje, Croatia; 96 mm SL.

above anal, usually slightly interrupted, usually with 51–70 pored scales. Size up to 165 mm SL.
Distribution. Croatia: Lika-Jadova, Ričica and Otuca drainages.
Habitat. In streams and sources with clear (often cold) water. Enters subterranean waters during winter or droughts.
Biology. Females spawn for the first time at about 66 mm SL, males at about 52 mm SL. Spawns in May, probably also later.
Conservation status. EN B1ab(i,ii,iii,iv,v) + ab (i,ii,iii,iv,iv), threatened by introduction of *Alburnus arborella*, *Squalius cephalus* and *Lepomis gibbosus*, by habitat destruction and pollution.
Further reading. Steindachner, 1866 (description); Bogutskaya & Zupančič, 2003 (morphology).

Telestes fontinalis

Common name. Spring pijor.
Diagnosis. Distinguished from other species of *Telestes* by: ○ scales very thin, not overlapping / ○ skin not thickened, scales clearly visible, covering whole body, often narrowly to widely separated in particular in pre-pelvic area / ○ conspicuous broad dark midlateral stripe from eye to end of caudal peduncle within pigmented area on back and flank (Fig. 54b) / ○ 7½ branched dorsal and anal rays / ○ snout stout, markedly rounded,

Telestes beoticus

Telestes croaticus

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Telestes fontinalis; Krbava polje, Croatia; ~90 mm SL.

Telestes metohiensis; Cernica polje, Bosnia-Herzegovina; ~80 mm SL.

mouth subterminal / ○ lateral line short, interrupted, usually with 23–37 pored scales, ending in area between pectoral and anal. Size up to 80 mm SL.
Distribution. Croatia: karstic streams and springs in Krbava polje.
Habitat. In streams and springs with clear water. Enters subterranean waters during winter or droughts.
Biology. No data.
Conservation status. CR B1ab(i,ii,iv) + 2ab(i, ii,iv), threatened by water abstraction and introduction of *Salmo trutta* and *Oncorhynchus mykiss*.
Further reading. Karaman, 1972 :134 (description); Zupančič & Bogutskaya, 2002: 420 (description).

Telestes metohiensis

Common name. Striped pijor.
Diagnosis. Distinguished from other species of *Telestes* by: ○ scales very thin, not overlapping / ○ whole body covered by scales, often not overlapping, especially in pre-pelvic area / ● narrow dark midlateral stripe from opercle to caudal base, separated from dark area on back by an unpigmented stripe (Fig. 54a) / ○ 7–8½ branched dorsal rays / ○ 8½ branched anal rays / ○ snout stout, markedly rounded, mouth subterminal / ○ skin not thickened, scales distinct / ○ lateral line usually almost complete, if interrupted, only narrowly in a few places, with 51–70 total scales. Size up to 100 mm SL.

Telestes fontinalis

Telestes metohiensis

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Telestes montenegrinus; Lake Skadar drainage, Montenegro; ~100 mm SL.

Distribution. Streams and springs in Nevesinje, Gacko, Cernica and Dabar poljes, probably also Lukovac polje (Bosnia-Herzegovina); recorded in 1901 from Ljuta drainage (southern Croatia), not seen there since.
Habitat. Streams with clear water. In karstic areas, enters subterranean waters.
Biology. Females spawn for the first time at about 49–59 mm SL, males at about 44–55 mm SL. Ripe individuals found in May. Pectoral and pelvic longer in males than in females. Males have well developed conical tubercles covering whole body (except ventral surface of head) and all fins (except caudal) on inner and outer sides.
Conservation status. VU B1ab(ii,iii) + 2ab(ii,iii), threatened by habitat destruction and pollution.
Further reading. Steindachner, 1901: 197 (description); Bogutskaya & Zupančič, 2003 (morphology).

Telestes montenigrinus

Common name. Montenegro riffle dace.
Diagnosis. Distinguished from other species of *Telestes* by: ○ 45–49 + 2–3 lateral line scales / ○ usually 9½ branched anal rays / ○ eye diameter 3.4–3.5 times in HL, 1.1–1.3 times in interorbital distance / ○ snout pointed, not projecting beyond tip of upper lip / ○ conspicuous black midlateral stripe and conspicuous black line along lateral line (in preserved individuals). Size up to 160 mm SL.
Distribution. Lake Skadar basin (Montenegro, Albania).
Habitat. Inhabits a wide range of habitats from small mountain streams to lake shores.
Biology. Spawns in April – May. Reportedly feeds on plankton and bottom fauna.
Conservation status. LC. Very abundant but restricted range.
Further reading. Vuković, 1963: 205, 1965: 217 (description); Sorić, 1983: 135 (description); Drecun et al, 1985: 76 (biology); Kottelat, 1997: 69 (systematics).

Telestes muticellus

Common name. Italian riffle dace.
Diagnosis. Distinguished from other species of *Telestes* by: ○ conspicuous black midlateral stripe and conspicuous black line along lateral line (in preserved individuals; in life: broad gold-orange stripe; lateral line yellow, bordered on each side by a narrow black line) / ○ 43–49 + 2–3 lateral line scales / ○ 3½ scale rows between lateral line and pelvic origin / ○ 8½ branched anal rays / ○ tip of snout rounded, snout projecting beyond tip of upper lip / ○ eye diameter 3.3–3.6 times in HL.

Telestes montenigrinus

Telestes muticellus

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Telestes muticellus; Lake Lugano basin, Switzerland; 136 mm SL.

Telestes muticellus; Lake Garda basin, Italy; ~120 mm SL.

Size up to about 170 mm SL.

Distribution. Adriatic basin, from Brenta to Vomano drainages (Italy, Switzerland); Tyrrhenian basin, from Bevera (French-Italian border) to Volturno drainages (Italy). Introduced to Liguria and southern Italy.

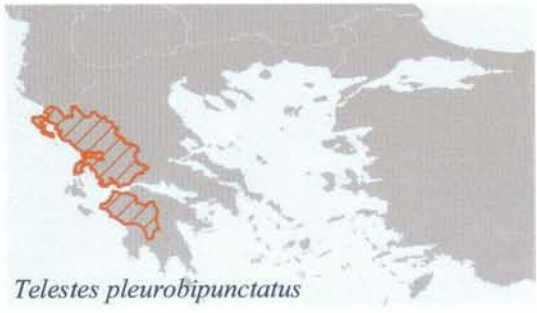
Habitat. Prefers streams of piedmont and hilly areas, with moderately cold water, but may be found in most habitats.

Biology. Spawns for the first time at 2–3 years. Spawns in May – June, in areas with swift, shallow waters. Feeds mainly on aquatic invertebrates, also on epilithic algae.

Conservation status. LC.

Remarks. Correct spelling of species name is *'muticellus'*, not *'multicellus'*.

Further reading. Gandolfi et al., 1991: 145 (biology); Bianco, 1995a: 165 (distribution); Kottelat, 1997: 70 (systematics); Bănărescu & Herzig-Straschil, 1998: 411 (systematics); Stefani et al., 2004 (genetics).



Telestes pleurobipunctatus

Telestes pleurobipunctatus

Common name. Epiros riffle dace.

Diagnosis. Distinguished from other species of *Telestes* by: ○ conspicuous black midlateral stripe and conspicuous black line along lateral line (in preserved individuals; in life: broad gold-orange stripe; lateral line yellow, bordered on each side by a narrow black line) / ○ 43–49 + 2–3 lateral line scales / ○ 8–10½ (usually 9½) branched anal rays / ○ snout rounded, projecting beyond upper lip / ○ eye diameter 3.8–4.0 times in HL, 1.3–1.5 times in interorbital distance / ● pharyngeal teeth in one row (5–5). Size up to about 140 mm SL.

Distribution. Southern Albania and Western Greece: Corfu Island and from Butrintit to Alfios drainages.

Habitat. Streams, with moderate to swift current, often in cavities along shores.

Biology. Lives up to 4 years. Spawns for the first time at 2 years. Spawns in April – May. Eggs ad-

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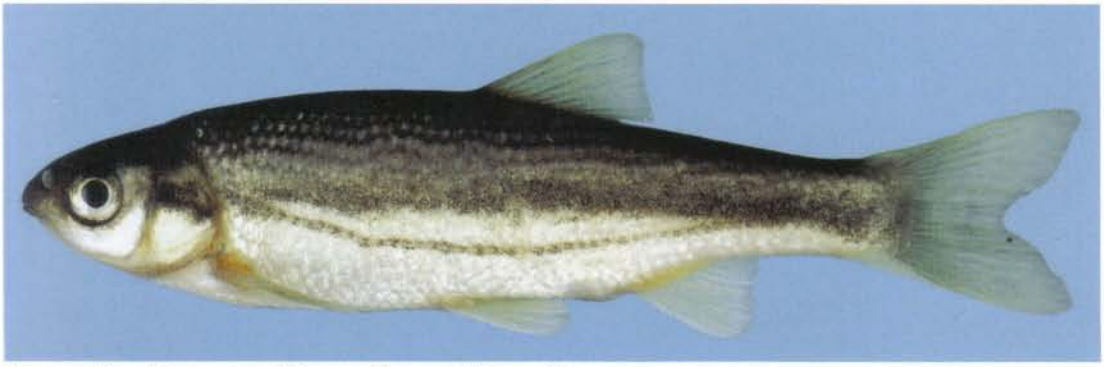


Telestes pleurobipunctatus; Kalamas, Greece; 100 mm SL.

Telestes polylepis; Stajnička Jaruga, Croatia; 91 mm SL.

hesive, 1.9 mm in diameter. Feeds mainly on insect larvae, supplemented by other animal and plant materials.

Conservation status. LC. Broad distribution and ecological tolerance render it reasonably safe, but water abstraction is a serious concern over most of its range.

Further reading. Stephanidis, 1939a: 19 (description), 1971a: 183 (description); Barbieri et al., 2002a: 61 (biology).

Telestes polylepis

Common name. Croatian riffle dace.

Diagnosis. Distinguished from other species of *Telestes* by: ○ conspicuous black midlateral stripe (in preserved individuals) / ○ 67–79 (usually 68–75) total lateral line scales / ○ 8½ branched anal rays / ○ 6–7 gill rakers / ○ depth of caudal peduncle 2.1–2.7 times in its length. Size up to 150 mm SL.

Distribution. Croatia: Stajnička Jaruga; historical records from Zagorska Drežnica, Dobra and Mrežnica drainages not confirmed.

Habitat. In clear streams and springs. Enters subterranean waters during winter or droughts.

Biology. Spawns in June – July. Omnivorous.

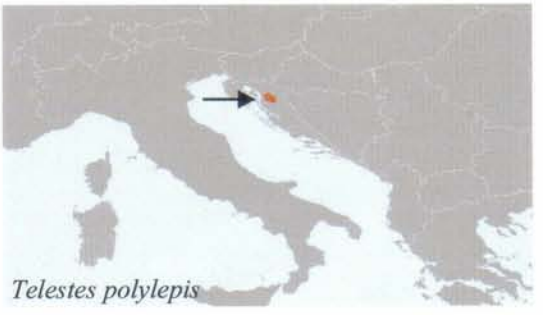
Conservation status. CR B1ab(ii,iii,v) + 2ab(ii, iii,v), threatened by water abstraction, pollution and introduction of *Salmo trutta*. On the very edge of extinction. A single small population known.

Further reading. Bănărescu & Herzig-Straschil, 1998: 412 (description); Trgovčević, 1905: 17 (biology, distribution).

Telestes souffia

Common name. Riffle dace.

Diagnosis. Distinguished from other species of *Telestes* by: ○ conspicuous black midlateral stripe and conspicuous black line along lateral line (in preserved individuals; in life: broad gold-orange stripe; lateral line yellow, bordered on each side by a narrow black line) / ○ 44–57 + 2–3 (usually 50–57 + 2–3) lateral line scales / ○ 4½–5 scale rows between lateral line and pelvic origin / ○ usually 9½ branched anal rays / ○ tip of snout rounded or blunt, snout projecting beyond tip of



Telestes polylepis

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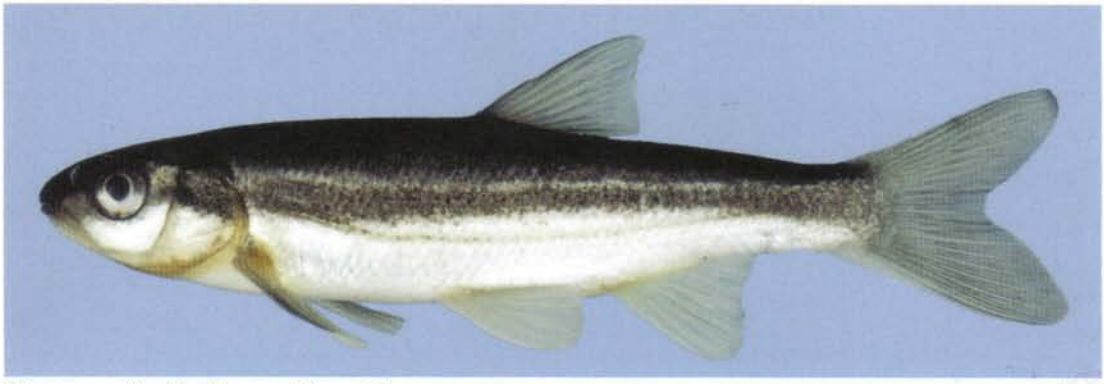
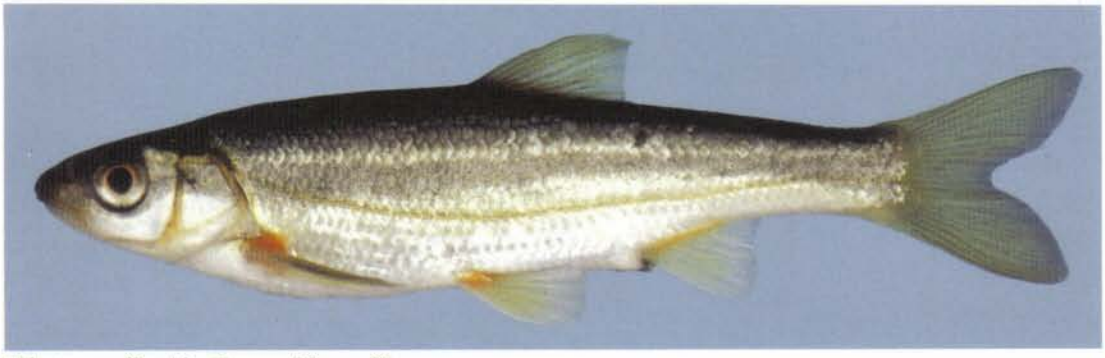


Telestes souffia; Var, France; 70 mm SL.



Telestes souffia; Ain, France; 98 mm SL.

upper lip / ○ eye diameter 4.0–4.6 times in HL. Size up to about 200 mm SL.

Distribution. Mediterranean basin, from Aude to Var drainages (France, Switzerland; literature records from Tarn system [Garonne drainage] in fact refers to Hérault [each has a tributary named Dourbie]); Soca drainage (Italy, Slovenia); uppermost Rhine drainage in Germany and Switzerland; Danube drainage: western tributaries in Germany, Austria, Slovenia, Croatia and part of Bosnia-Herzegovina, and upper Tisza system (Romania, Ukraine). Record from Aegean basin in Bulgaria based on misidentification of a possibly unnamed species. Introgression zone with *T. muticellus* in Var (France) and Soca (Slovenia, Italy) drainages.

Habitat. Middle reaches of streams and rivers with clear water, moderately swift current and gravel bottom. Spawns in fast-flowing water on gravel bottom.

Biology. Gregarious. Spawns for the first time at 3 years. Spawns in March – May when temperature rises above 12°C, only once in each season. Feeds on invertebrates and algae.

Conservation status. LC. Locally threatened.

Remarks. *T. souffia agassii* is often used for the Danube and Rhine populations, but there is no published evidence that they differ from the Rhône populations. In any event, if it were justified, the correct name for a Danube-Rhine species would be *T. rysela* and not *T. agassii*.

Further reading. Spillmann, 1959: 491, 1967: 502 (morphology); Kottelat, 1997: 70 (systematics); Bănărescu & Herzig-Straschil, 1998: 407 (description); Salzburger et al., 2003 (genetics).

Telestes souffia

Telestes turskyi

Common name. Čikola riffle dace.

Diagnosis. Distinguished from other species of *Telestes* by: ○ conspicuous black midlateral stripe (in preserved individuals) / ○ 71–79 total lateral line scales / ○ 8½ branched anal rays / ○ 7½ branched dorsal rays / ○ 8–9 gill rakers / ○ depth of caudal peduncle 2.0–2.2 times in its length. Size up to 160 mm SL.

Distribution. Croatia: Čikola (Krka drainage).

Habitat. Slow-flowing and still water. Possibly

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Telestes turskyi; Čikola, Krka drainage, Croatia; ~120 mm SL.

Telestes ukliva; Cetina, Croatia; 142 mm SL.

enters subterranean waters during winter or droughts.
Biology. No data.
Conservation status. CR B1ab(ii) + 2ab(ii), threatened by water abstraction and pollution.
Further reading. Bănărescu & Herzig-Straschil, 1998: 415 (description).

Telestes ukliva

Common name. Ukliva.
Diagnosis. Distinguished from other species of *Telestes* by: ○ conspicuous black midlateral stripe / ○ 58–66 + 3 lateral line scales / ○ usually 9½ branched anal rays / ○ tip of snout rounded or blunt, snout projecting beyond tip of upper lip / ○ dark brown peritoneum / ○ 6–8 gill rakers. Size up to 100 mm SL.
Distribution. Croatia: Cetina drainage.
Habitat. In slow-flowing and still water.
Biology. No data.
Conservation status. VU D2*.
Further reading. Bănărescu & Herzig-Straschil, 1998: 421 (description).

Tropidophoxinellus hellenicus

Common name. Gournara.
Diagnosis. Distinguished from *T. spartiaticus* by: ● mouth opening upward, lower jaw projecting beyond upper jaw / ○ 37–40 +2 lateral line scales. Size up to 93 mm SL.

Telestes turskyi

Telestes ukliva

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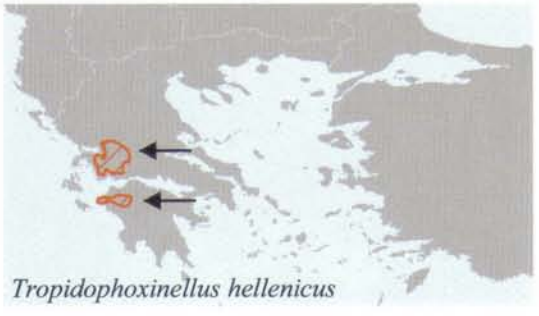
Tropidophoxinellus hellenicus; Pinios (Peloponnese), Greece; 63 mm SL.

Tropidophoxinellus spartiaticus; Evrotas, Greece; 62 mm SL.

Distribution. Greece: Acheloos and Pinios (Peloponnese) drainages.
Habitat. In lakes: open waters, near surface; in streams: in deep areas.
Biology. Forms schools in open water. Lives up to 4 years. Spawns for the first time at 1–2 years. Spawns in April – July. Lays adhesive eggs on aquatic vegetation. In Lake Trichonis, feeds mainly on zooplankton in spring and mainly on phytoplankton in July – February, in addition to diatoms. In lakes, larvae school along shoreline.
Conservation status. LC. Lacustrine populations relatively safe, riverine ones have apparently declined in recent years.
Remarks. Two or more species are probably confused under the name *T. hellenicus*.



Tropidophoxinellus hellenicus

Further reading. Stephanidis, 1974b: 249 (description); Daoulas, 1984 (reproduction), 1985 (feeding), 1986 (feeding); Economou et al., 1994a: 22 (larvae); Barbieri et al., 2002a: 58 (biology).

Tropidophoxinellus spartiaticus

Common name. Bafa.
Diagnosis. Distinguished from *T. hellenicus* by: ● mouth terminal, upper jaw projecting slightly beyond lower jaw / **O** 40–44 + 2–3 lateral line scales. Size up to 95 mm SL.
Distribution. Greece: southern Peloponnese, from Nedas to Evrotas drainages.
Habitat. Springs and stretches of streams with moderate current.
Biology. Lives up to 4 years. Males smaller and more slender than females, in spawning season with whitish tubercles on head, back and pectoral fins. Spawns in April – May. Eggs adhesive, 1.6 mm in diameter. Feeds on small aquatic insects and invertebrates.
Conservation status. VU B1ab(ii,iii,iv,v) + 2ab(ii, iii,iv,v). Most populations inhabit small streams and are very sensitive to water abstraction and pollution. Populations in a few large springs seem safe.
Further reading. Stephanidis, 1974b: 246 (description); Barbieri et al., 2002a: 60 (biology).

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Vimba melanops; Maritza, Greece; 191 mm SL.

Vimba

Vimba are medium-sized species, which inhabit the lower and middle reaches of warm rivers. They are variable in size, colour and ecology. Some populations are semi-anadromous, others are restricted to the middle reaches of rivers; there are populations with very small individuals only, while others grow large. This variability has lead to the description of many taxa below the species level, which are now treated as synonyms. This is also the case for the subalpine *Vimba*, which are sometimes recognised as *V. elongata*. Several populations of subalpine *Vimba* show slight differences and might be distinguished from *V. vimba*. This is possibly the result of peripheral isolation (see Box under *Cottus*) and studies are needed to distinguish genetically based adaptation from environmental plasticity.

Vimba melanops

Common name. Dark vimba.

Diagnosis. Distinguished from other species of *Vimba* in Europe by: ● back not keeled behind dorsal base / ○ 15–18½ (usually 16½) branched anal rays / ● in spawning season, males with a broad black midlateral stripe, belly and cheek white. Size up to 280 mm SL.

Distribution. Northern Aegean basin, from Maritza to Pinios drainages (Turkey, Greece, Bulgaria, Macedonia).

Habitat. Rivers and streams, usually with relatively swift current.

Biology. Spawns in May – June among stones in large rivers.

Conservation status. DD.

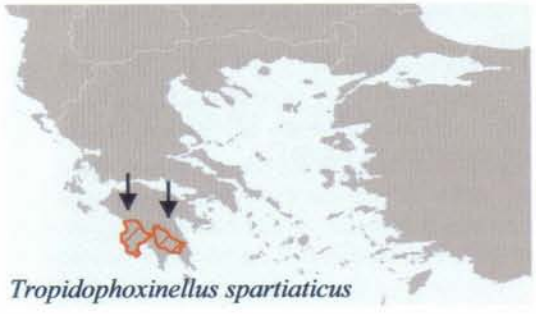
Further reading. Stephanidis, 1937: 263 (description); Bănărescu et al., 1970: 61 (description).

Vimba vimba

Common name. Vimba.

Diagnosis. Distinguished from other species of *Vimba* in Europe by: ● back keeled behind dorsal base / ○ 16–21½ branched anal rays / ● in spawning season, males blackish brown with orange cheek and sometimes belly. Size up to 350 mm SL, in many populations much smaller.

Distribution. Caspian, Black, Marmara and Baltic Sea basins (Sweden and Finland north to 63°N), North Sea basin from Elbe to Ems drainages. In Finland restricted to coastal waters. In Anatolia: in Marmara basin, south to Great Menderes and



Tropidophoxinellus spartiaticus

Vimba melanops

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Vimba vimba; Krka, Danube drainage, Slovenia; nuptial male, ~300 mm SL.

Vimba vimba; Danube, Austria; ~65 mm SL. A. Hartl

Lake Egridir and east to Kızılırmak drainage. Absent between Kızılırmak and Çoruh drainages. Extirpated in Crimea. Introduced in Rhine.

Habitat. Brackish estuaries, large to medium rivers and some large subalpine lakes. Sedentary populations occur even in small rivers of barbel zone. Spawns on gravel in riffles in shallow, fast-flowing streams and rivers.

Biology. Lives up to 15 years. Spawns for the first time at 3–5 years. Spawns in May – July (April in Terek and some subalpine lakes) when temperature rises above 15°C. Semi-anadromous populations forage in freshened parts of sea and undertake long distance spawning migrations. Lacustrine populations migrate to fast-flowing tributaries. In Dniepr and Kuban, spawning migration starts in September, decreases in winter and resumes in March – May. Individual females spawn several times during a period of 2–3 weeks. Usually spawns for several years. Spent adults return to foraging habitats. Feeds predominantly on small molluscs and insect larvae.

Conservation status. LC*, but semi-anadromous populations now rare in Black and Baltic Sea basins.

Further reading. Bănărescu et al., 1963: 398 (systematics), 1970: 69 (systematics); Balon et al., 1987: 241 (morphology, hybrids); Freyhof, 1999 (introduction in Rhine).

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Subfamily Squaliobarbinae

Grass carp, black carp

This subfamily includes only three species in three genera (*Squaliobarbus*, *Ctenopharyngodon*, *Mylopharyngodon*) native to East Asia, from the Amur drainage to central Vietnam. They reach large sizes, grow rapidly and two have been cultivated and introduced world wide. Their relationships with other subfamilies are not clear. Different authors have grouped them with different subfamilies and/or groups of genera (for example, with Cyprininae, Leuciscinae, Xenocyprinidae, or as a distinct lineage with *Hypophthalmichthys*). None of these groupings seems natural on the basis of the available information, for which reason we retain them as a distinct subfamily. Recently, molecular studies have given some support to the hypothesis that they might form a distinct lineage together with *Hypophthalmichthys*, *Ochetobius* and possibly *Elopichthys* and *Luciobrama*. This hypothesis is contradicted by the morphological data presently available.

Further reading. Howes, 1981 (anatomy); Chen, 1987 (phylogeny); Cunha et al., 2002 (genetics).

Ctenopharyngodon idella

Common name. Grass carp.

Diagnosis. Only species in genus. Distinguished from rather similar *Mylopharyngodon piceus* by: ● body olive to brassy green above, silvery white to yellow below / ○ body cylindrical / ● pharyngeal teeth laterally compressed, serrated, with a groove along grinding surface, usually in two rows, 2,5–4,2 (Fig. 55). Size up to 1200 mm SL and 32 kg.

Distribution. Native to East Asia, in most major Pacific drainages from Amur to Xi Jiang. Used in aquaculture in Europe, Asia and North America; released in most large drainages in Europe. Established reproductive populations in North America.

Habitat. Spawning and overwintering in middle and lower stretches of large rivers (below 1000 m); lakes, reservoirs and backwaters during feeding season, preferably with warm clear water and high oxygen concentrations. Inhabits rivers with prominent water-level fluctuations caused by floods.

Biology. In the wild, spawns for the first time at 7–10 years and about 600–800 mm SL, females 1–2 years later than males. Spawns in April – August. Migrates upriver and spawns during periods of high water, in upper water layer or at surface in stretches with strong current. Females lay one or several portions of eggs depending on length of high-water period. Average female spawns about 1.5 million eggs. Eggs are pelagic and hatch while drifting downstream in 2–3 days; if the river flow is blocked or if available river stretches are too short, eggs cannot drift for long enough and fail to develop. After spawning, adults leave the river and migrate to flooded regions, lakes or backwaters with dense vegetation. In autumn – winter, they return to rivers, spending the cold period in deep places in lower stretches. Larvae settle into floodplain lakes and channels with little or no current after about a 1000 km downstream migration. Larvae feed on phyto- and zooplankton, then, from about 25–50 mm SL, on aquatic macrophytes.

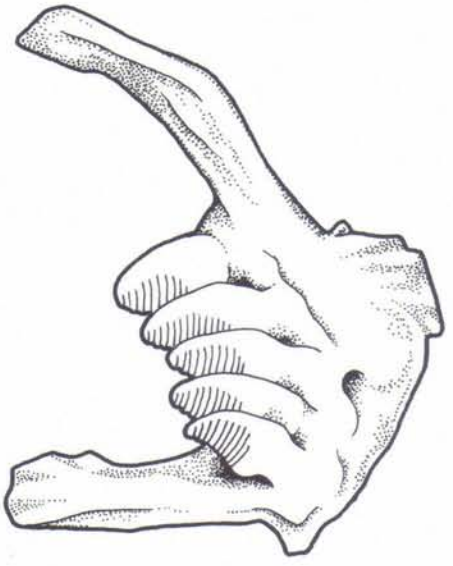

Figure 55 Frontal view of left pharyngeal arch of *Ctenopharyngodon idella* (the two small teeth of row 1 are not visible in frontal view) (after Nico et al., 2005).

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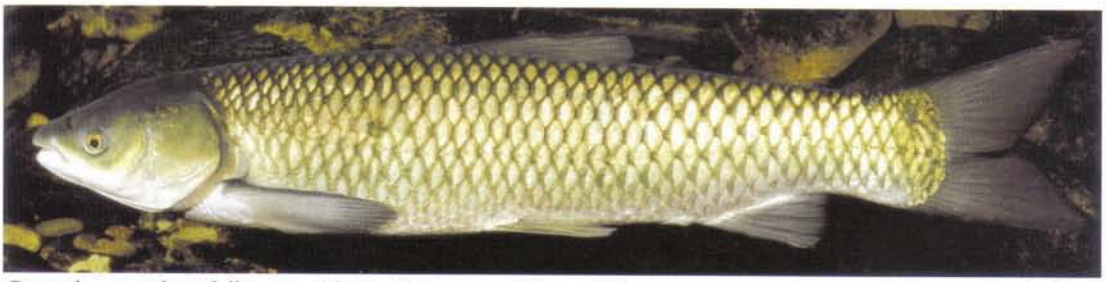

Ctenopharyngodon idella; aquaculture, Germany; ~600 mm SL. A. Hartl

Mylopharyngodon piceus; Vietnam; ~600 mm SL.

Larger juveniles and adults basically feed on macrophytes including terrestrial ones during monsoon floods in summer. Does not feed during winter. There are reliable data on natural spawning in non-native rivers in southern Russia, but the success of these reproductive events is not known.

Conservation status. Alien. In Europe, persists only by stocking. Native stocks in eastern Russia and China declining.

Further reading. Biro, in Bănărescu, 1999: 305 (biology); Nico et al., 2001: 15 (comparison with *Mylopharyngodon*).

Mylopharyngodon piceus

Common name. Black carp.

Diagnosis. Only species in genus. Distinguished from rather similar *Ctenopharyngodon idella* by: ● body black, blue grey or dark brown / ○ body slightly compressed / ● pharyngeal teeth molar-like, massive, smooth, very strong (Fig. 56). Size up to 1800 mm SL, up to over 60 kg.

Distribution. Native in most major Pacific drainages, from Amur to Xi Jiang. Used in aquaculture; stocked in Danube, Dniestr, Dniepr, Don, Kuban and Volga drainages. No longer stocked outside Russia. Naturally reproducing populations established only in Amu Darya (Turkmenistan) and possibly in Tone drainages (Japan), not in Europe. Introduced for control of populations of molluscan vectors of fish and human parasites. Commonly used to remove *Dreissena* mussels that clog hydroelectric plants.

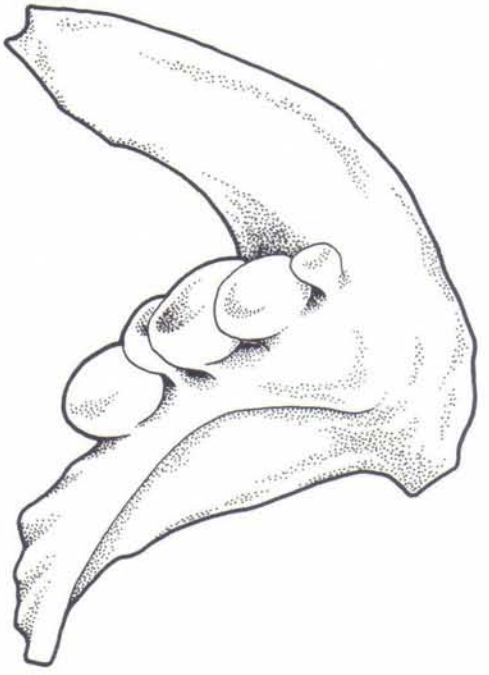

Figure 56 Frontal view of left pharyngeal arch of *Mylopharyngodon piceus* (after Nico et al., 2005).

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Habitat. Large lowland rivers and lakes, preferably with clear water and high oxygen concentrations.

Biology. Spawns for the first time at 6–11 years, females later than males, at about 1000 mm SL and 15 kg, males at 900 mm and 11 kg. Migrates upriver and spawns in open waters in March – July. Spawns when water level rises, at 19–30°C. Eggs are pelagic or semipelagic and hatch while drifting downstream. If the river flow is blocked or if available river stretches are too short, eggs cannot drift for long enough and fail to develop. Larvae settle into floodplain lakes and channels with little or no current. Larvae feed on zooplankton, then on ostracods and aquatic insects. At about 120 mm SL, juveniles start to feed on small snails and clams; larger juveniles and adults feed almost entirely on molluscs.

Conservation status. Alien in Europe where it persists only by stocking or accidental releases. At present, a single farm on lower Kuban still produces fry for stocking. Native stocks in Russia and China have declined sharply.

Further reading. Evtushenko et al., 1993 (biology); Biro, in Bănărescu, 1999: 347 (biology); Nico et al., 2001 (biology, introductions), 2005 (synopsis).

Hot spring Petzea, near Oradea, Romania; only known habitat of *Scardinius racovitzai*.

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Subfamily Tincinae

Tench

The subfamily Tincinae includes only *Tinca tinca*. The relationships of this species are not yet clear and in recent years it has been placed in the Leuciscinae or the Cyprininae. *T. tinca* is in fact distinguishable from both subfamilies and we retain it in a separate subfamily.

Tinca tinca

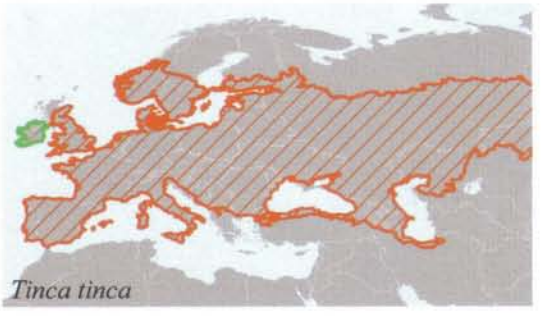
Common name. Tench.

Diagnosis. Single species of genus. Distinguished from other species of Cyprinidae in Europe by: ○ golden greenish brown body / ○ one pair of barbels (maxillary) / ○ 96–115 total lateral line scales, small and deeply embedded / ○ 6–9½ branched anal rays / ○ 8–9½ branched dorsal rays. Size up to 600 mm SL.

Distribution. Stocking throughout Europe for centuries has blurred the original distribution pattern. Hypothesised to be native in most of Europe, naturally absent only in Ireland, Scandinavia north of 61°30'N, eastern Adriatic basin and western and southern Greece where it is now introduced. In Asia, native eastward to western Yenisei drainage south of 60°N. Introduced to North and South Africa, Tasmania, Australia, New Zealand, India, North America, Chile and probably elsewhere.

Habitat. Typically in shallow, densely vegetated lakes and backwaters. Often overwinters buried in mud. Spawns among dense vegetation in still water.

Biology. Lives up to 20 years. Spawns for the first time at 2–6 years and 70–250 mm SL, females a year later than males. Pelvic rays more robust, longer and extending beyond anus in male. Spawns in May – October, in Central Europe usually in June – July, at temperatures above 19°C, mostly at 22–24°C. Several males follow a female, which releases eggs in several portions above vegetation.



Tinca tinca

Tinca tinca; upper Danube drainage, Germany; ~350 mm SL. A. Hartl

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Females may spawn 1–9 times each year, every 11–15 days, if suitably warm weather persists. High embryonic mortality observed when temperature fluctuates strongly. Larvae and juveniles restricted to dense vegetation. Tolerant of low oxygen concentrations and salinities up to 12 ‰. Feeds on detritus, benthic animals and plant material. Adults often feed predominantly on molluscs.

Conservation status. LC. Locally threatened by river engineering.

Further reading. Bogutskaya, 1986, 1988b (osteology, phylogeny); Brylińska et al., in Bănărescu, 1999: 229 (biology).

Spring in Evrotas drainage, Greece; habitat of *Pelasgus laconicus*, *Squalius keadicus* and *Tropidophoxinellus spartiaticus*.

Suran, Rhône drainage, France; habitat of *Telestes souffia*, *Parachondrostoma toxostoma* and *Squalius cephalus*.

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Family Catostomidae

Suckers

A small family with about 70 species in 12 genera native to North and Middle America from Alaska to Guatemala and two species in two genera in northeastern Asia. Strictly freshwater fishes specialised for feeding on bottom organisms. They are distinguished by the presence of numerous comb-like pharyngeal teeth in a single row (Fig. 57) and the inferior mouth with large, papillose lips in most species. They are related to loaches (Cobitidae, Botiidae, Nemacheilidae, Balitoridae). In the early Cenozoic, suckers were widespread in east and central Asia and the Chinese *Myxocyprinus asiaticus* could be a relict of this period. As with many other groups of freshwater fishes, Catostomidae are hypothesised to have invaded North America from Siberia. *Catostomus catostomus* whose range extends across northern North America to southeastern Siberia is usually interpreted as a Quaternary 're-immigrant' from America to Asia.

Four species of Catostomidae are often listed as introduced to European waters. We have not found evidence that they have established breeding populations. *C. catostomus* was introduced in 1978 from Siberia to Kopore, Neva and Kovashi drainages (Russia). It is believed to be locally established in streams draining to the Gulf of Finland, but there is no recent evidence that it is still present. *Ictiobus bubalus*, *I. cyprinellus* and *I. niger*, native to North America, were introduced to eastern Europe in the early 1970s and cultivated in fish farms in Hungary, Romania, Poland, Czechia, Slovakia and Russia. At that time, these species were locally stocked in natural waters. As these fishes failed to meet a market, most European breeders gave up and there is reportedly a single farm in Poland and one in southern Russia that still keep them. There are no records of *Ictiobus* species outside of farm ponds.

The Catostomidae introduced to Europe are distinguished from similar cyprinids (e.g. *Cyprinus*, *Carassius*, *Barbus*) by having 24–31½ branched dorsal rays (vs. 11–25½), last simple dorsal ray not serrated posteriorly (vs. serrated), no barbels (vs. 2 pairs in *Cyprinus* and *Barbus*) and numerous comb-like pharyngeal teeth in a single row (vs. 1–3 rows of 1–5 teeth). *Ictiobus* species are long lived (at least 8 years), large-growing, carp-like fishes reaching about 700 mm SL (*I. bubalus*), 450 mm SL (*I. cyprinellus*), 600 mm SL (*I. niger*), inhabiting large rivers and feeding on benthic organisms or plankton. They spawn in late spring in pools and backwaters and the eggs are scattered over the bottom. Potential escaped *Ictiobus* can be identified using the key below. *C. catostomus* is a large (up to 600 mm SL), barbel-like species inhabiting clear, cold lakes, streams and rivers, feeding on benthic invertebrates and spawning in early spring in fast-flowing water where it forms large spawning aggregations.

Further reading. Jenkins & Burkhead, 1993: 462 (biology); McPhail & Taylor, 1999 (*C. catostomus*); Smith, 2002: 147 (biology); Piller et al., 2003 (*Ictiobus*, reproduction).

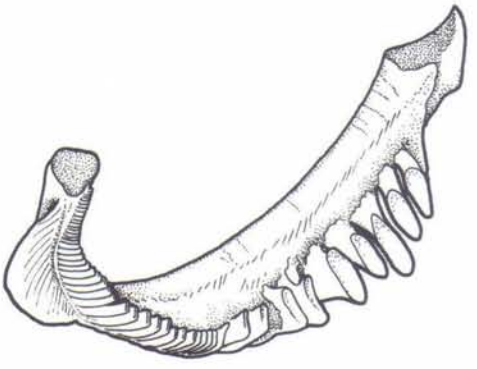

Figure 57 Left pharyngeal arch of Catostomidae (after Jenkins & Burkhead, 1994).

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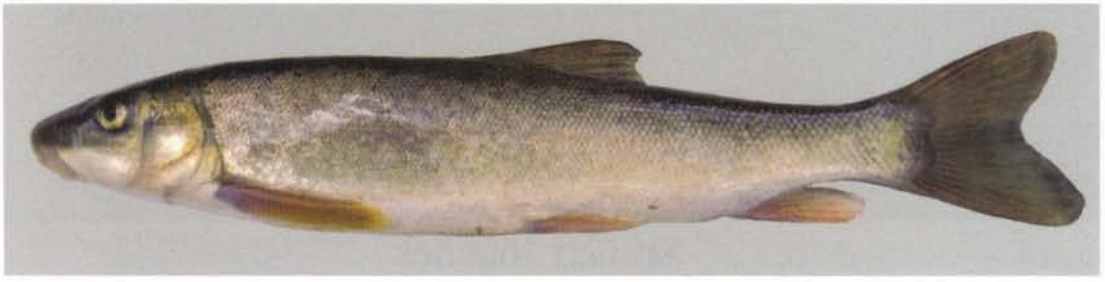

Catostomus catostomus; Canada; ~180 mm SL. R. J. Zemlak

Key to species of Catostomidae recorded from European waters

1a – 9–11½ branched dorsal rays; 92–117 + 3 lateral line scales. ..... *Catostomus catostomus*

1b – 24–31½ branched dorsal rays; 32–36 + 3 lateral line scales. 2

2a – Mouth large, terminal and oblique; tip of upper lip about level with lower margin of eye. ..... *Ictiobus cyprinellus*

2b – Mouth small, subterminal or inferior; tip of upper lip well below level of lower margin of eye. 3

3a – Back not keeled in front of dorsal; body depth 2.8–3.1 times in SL ..... *Ictiobus niger*

3b – Back keeled in front of dorsal; body depth 2.0–2.8 times in SL. ..... *Ictiobus bubalus*

Spring in Cernica polje, Bosnia-Herzegovina; one of the few habitats of *Telestes metohiensis*, which is the only fish species at this locality.

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Family Cobitidae

Spined loaches

A family of mainly small, slender fishes found in Europe, Asia and Morocco (North Africa), most abundant and diverse, however, in Southeast Asia. There are some 130 species in 16 genera. The family earlier included species now placed in the families Botiidae, Nemacheilidae and Balitoridae. They are distinguished by the presence of an erectile, movable, bifid, suborbital spine (Fig. 58), which is hidden under the skin in some species. Most species are elongate and live on or in river bottom. Many species exhibit external sexual dimorphism. Very often the male has modified rays in the pectoral and is smaller than the female. *Sabanejewia* lack size differences between sexes, but exhibit vertical swellings of the flanks in male (Fig. 59). *Misgurnus* males have horizontal swellings of the flanks behind dorsal fin. Some 45 species of *Cobitis* are known from most of Europe and temperate Asia (except the very north) and Morocco. *Sabanejewia* occurs in Europe, Caspian and Aral basins and *Misgurnus* in Europe and East Asia. The taxonomy of *Sabanejewia* and *Misgurnus* is far from resolved and species numbers are only vaguely known.

Cobitis and *Misgurnus* are usually associated with fine substrate (sand, mud), from which they feed during the night. *Cobitis* burrow in the substrate to hide during daytime. *Sabanejewia* is often associated with gravel bottom. A specialised filter feeding mechanism enables *Cobitis* to separate fine organic particles and small benthic organisms (copepods, worms, insect larvae) from the substrate. *Cobitis* and *Misgurnus* can swallow air, oxygen being absorbed through the walls of the gut. The free larvae have large external gill filaments.

Typical elements of the pigmentation of spined loaches are a row of dark blotches along flank, another along dorsal mid-line, a regular or irregular dotted pattern between these rows and one or two black spots on caudal base (sometimes fused to form a bar in *Sabanejewia*). The pigmentation pattern is important for identification, especially the markings on the dorsal half of the body and the prominent black spots at caudal base (Fig. 60). In *Cobitis*, in addition to the mid-dorsal row of blotches, the body pigmentation is usually organised into four longitudinal zones of pigmentation (Z1 to Z4, see Fig. 60) (also known as Gambetta's zones 1-4). Males of *Cobitis* have one or two lam-

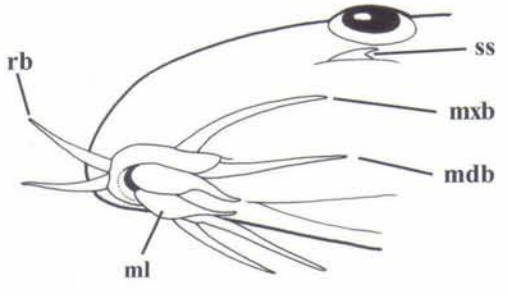

Figure 58 Head of Cobitidae. **mdb,** mandibular barbel; **ml,** mental lobe on lower lip ; **mxb,** maxillary barbel; **rb,** rostral barbel; **ss,** suborbital spine (after Nalbant, 1963).

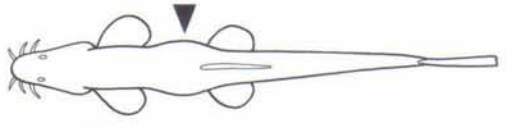

Figure 59 Vertical swelling (arrow) of male *Sabanejewia*.

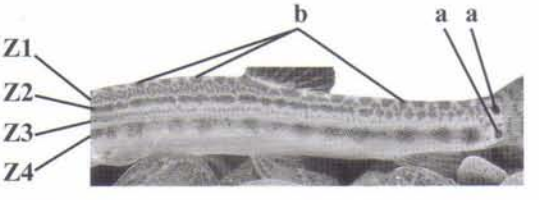

Figure 60 Colour marks on body of *Cobitis* species. **a,** black spots at caudal base; **b,** mid-dorsal blotches; **Z1-4**, longitudinal zones of pigmentation

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Cobitis triploid hybrid female; upper Volga drainage, Russia; ~75 mm SL.

Cobitis elongatoides, Danube delta, Romania; foraging.

inar projections on the dorsal surface of the anterior pectoral rays (lamina circularis, plural laminae circularis, also known as Canestrini scales; Fig. 61); in two European species these projections are absent.

Several species of *Cobitis* and *Sabanejewia* are morphologically very similar, but biochemical and genetic investigation have shown that they are in fact distinct. Spawning behaviour is the same in all species of *Cobitis* in which it has been observed: the male follows the female and, after both enter dense vegetation (e.g. filamentous algae), the male forms a complete ring around the female's body behind the dorsal as the female releases the eggs. The eggs of most species are not sticky, but swell to 2.5–3.5 mm in diameter and, because of this large size, are retained in the vegetation.

There are several hybridogenous lineages in the species of *Cobitis* of central and eastern Europe. These are lineages of hybrid origin that reproduce by gynogenesis. These lineages are nearly all-female. They are described as sperm-parasites as they are dependent on males of bisexually reproducing lineages that serve as sperm donor, the sperm serving only to induce development of their eggs. They have, therefore, to occur in sympatry with one of the parental species, forming 'hybrid complexes'. Within a hybrid complex, individuals belonging to hybridogenous lineages are not or difficultly distinguishable by external characters from individuals of bisexual parent species and therefore are not diagnosed here. Frequently, hybridogenous individuals are more abundant in a given hybrid complex than the parent species. An unbalanced sex ratio with much more females than males is a good indicator that hybridogenous lineages are present.

Further reading. Nalbant, 1963 (genera); Sawada, 1982 (morphology); Kottelat, 1986 (nomenclature), 2004b (Botiidae); International Commission on Zoological Nomenclature, 1988 (nomenclature); Bohlen, 2003 (reproduction); Šlechtová et al., 2005 (Botiidae).

Key to genera of Cobitidae in Europe

1a – Suborbital spine hidden under muscles, not visible externally; lower lip with 4 long, barbel-like mental lobes (Fig. 62).
..... *Misgurnus*

1b – Suborbital spine visible externally; lower lip with 0–2 short barbel-like mental lobes (Fig. 58).
..... 2

2a – Body pigmentation usually organized in 1 dorsal and 2 lateral longitudinal zones (Fig. 63); 12 branched caudal rays.
..... *Sabanejewia*

2b – Body pigmentation usually organized in 1 dorsal and 4 lateral longitudinal zones (Fig. 60); 14 branched caudal rays.
..... *Cobitis*

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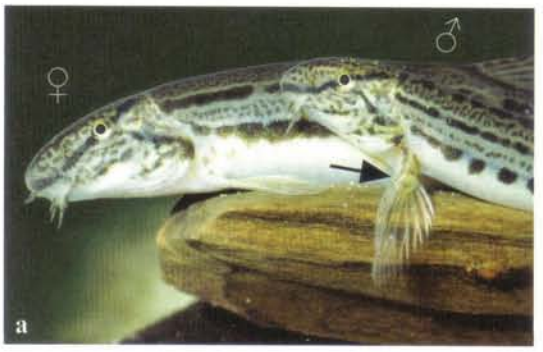

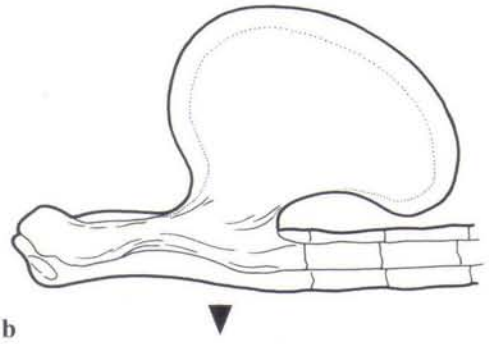

Figure 61 **a,** male and female *Cobitis* showing position of lamina circularis (arrow) on dorsal surface of anterior pectoral ray of male. **b,** lamina circularis, dorsal view, arrow points towards head (**a** by A. Hartl; **b** after Nalbant, 1993).

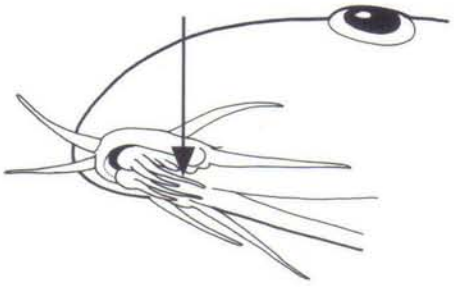

Figure 62 Mouth of *Misgurnus fossilis* (schematized) showing barbel-like mental lobes on lower lip (arrow).

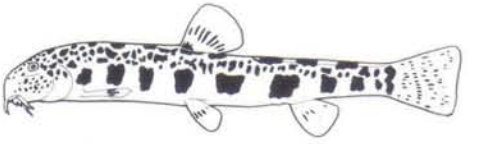

Figure 63 Colour marks on body of *Sabanejewia* species.

Key to species of *Cobitis* in Europe

Central, northern and eastern Europe

From northern France to Caspian basin, including British Isles, Scandinavia, Danube drainage and northern Black Sea basin. Excluding *Cobitis bilineata*, introduced in upper Rhine drainage.

1a – Male without lamina circularis; body depth 9–13 % SL. ..... *C. elongata*

1b – Male with 1 or 2 laminae circularis; body depth 13–19 % SL. 2

2a – Male with 2 laminae circularis. ..... *C. strumicae*

2b – Male with 1 lamina circularis. 3

3a – Two black spots at caudal base, lower one sometimes weakly marked. ..... *C. melanoleuca*

3b – A single black spot at caudal base. 4

4a - Zone Z3 usually narrower than zone Z2. ..... *C. tanaitica*

4b - Zone Z3 usually wider than zone Z2. 5

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5a - Black spot at caudal base about eye-size and oval or round.
..... *C. elongatoides*, *C. pontica*

5b - Black spot at caudal base very small (less than size of pupil), usually comma-shaped.
..... 6

6a – Height of blotches of zone Z4 usually 2 times in their length, less than horizontal eye diameter.
..... *C. taurica*

6b – Height of blotches of zone Z4 usually less than 2 times in their length, if more than 2 times, then height equal to or greater than horizontal eye diameter.
..... *C. taenia*

Iberian Peninsula

Excluding *C. bilineata*, introduced in Lake Bañolas.

1a – Male without lamina circularis; dorsal origin behind or above pelvic origin; body depth 9–11 % SL.
..... *C. calderoni*

1b – Male with 1 lamina circularis; dorsal origin before or above pelvic origin; body depth 11–20 % SL.
..... 2

2a – All barbels very small, hardly visible, mandibular barbel about 7–40 times in HL; pectoral fin length 4.9–8.6 times in SL in males, 6.9–13.5 times in females; 7½ branched dorsal rays (Alagón system, Tagus drainage).
..... *C. vettonica*

2b – Barbels clearly distinct, mandibular barbel 4–8 times in HL; pectoral fin length 4.3–5.4 times in SL in males, 4.3–9.0 times in females; 6–7½ branched dorsal rays (Iberian drainages other than Alagón system).
..... *C. paludica*

Central Mediterranean

Southeastern France, Italy and Croatia.

1a – Two black spots at caudal base.
..... *C. bilineata*

1b – A single black spot at upper caudal base, or no black spot.
..... 2

2a – Black spot on upper caudal base conspicuous, comma-shaped.
..... *C. narentana*

2b – Black spot on upper caudal base absent or inconspicuous.
..... 3

3a – Zone Z2 with large blotches, distinct from zones Z1 and Z3; zone Z3 with few spots, narrower than zone Z2 in both sexes.
..... *C. dalmatina*

3b – Zone Z2 with small blotches or spots, behind dorsal indistinguishable from zones Z1 and Z3; zone Z3 with many spots, wider than zone Z2 in females and most males.
..... 4

4a – Zone Z4 made of blotches until caudal base, blotches not dissociated into irregular spots posteriorly; depth of caudal peduncle 1.9–2.3 times in its length.
..... *C. illyrica*

4b – Zone Z4 not reaching caudal base, replaced by irregular spots, indistinguishable from those of zones Z2 and Z3 immediately in front of caudal; depth of caudal peduncle about 1.3 times in its length.
..... *C. zanandreai*

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Balkan Peninsula (excluding Danube drainage)

1a – Male with 1 lamina circularis.
..... 2

1b – Male with 2 laminae circularis.
..... 5

2a – Blotches of zones Z2 and Z4 very small, indistinct or confluent; flank pigmented below zone Z4; body brownish.
..... *C. puncticulata*

2b – Zone Z2 with well separated blotches; body pale yellowish or whitish.
..... 3

3a – Zone Z4 forming a continuous black or grey stripe until middle of caudal peduncle.
..... *C. stephanidisi*

3b – Zone Z4 with well separated blotches.
..... 4

4a – Zone Z3 narrower than zone Z2, comprising a single row of dots; dark spot at caudal base often small, faint or missing.
..... *C. ohridana*

4b – Zone Z3 wider than zone Z2, comprising several rows of dots; dark spot at caudal base large and distinct.
..... *C. vardarensis*

5a – 9–14 blotches on zone Z4, large, squarish, on caudal peduncle mostly vertically elongated; axial streak conspicuous along upper margin of blotches of zone Z4.
..... *C. trichonica*

5b – 9–50 blotches of zone Z4, not large and squarish, not vertically elongated on caudal peduncle; axial streak faint or indistinct along upper margin of blotches of zone Z4 conspicuous.
..... 6

6a – Blotches of zones Z2 and Z4 grey to olive, edges not sharply contrasted; zones Z1 and Z3 absent or very poorly defined and present only in anterior half of body.
..... *C. meridionalis*

6b – Flank with pigments clearly organised into 4 longitudinal pigmentation zones.
..... 7

7a – Blotches of zone Z4 numerous (usually more than 40); flank pigmented below zone Z4.
..... *C. punctilineata*

7b – 9–30 blotches on zone Z4; flank pigmented or not below zone Z4.
..... 8

8a – Zone Z3 absent in juveniles, in adults narrower than zone Z4, not densely pigmented.
..... *C. arachthosensis*

8b – Zone Z3 present in juveniles, in large adults wider than zone Z4, densely pigmented.
..... 9

9a – Flank not pigmented below zone Z4; zone Z3 not fused with zone Z1 on caudal peduncle.
..... *C. strumicae*

9b – Flank pigmented below zone Z4; zone Z3 fused with zone Z1 on caudal peduncle.
..... *C. hellenica*

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Cobitis arachthosensis; Arachthos drainage, Greece; 50 mm SL.

Cobitis bilineata; Stella, Italy; ~65 mm SL.

Cobitis arachthosensis

Common name. Arachthos spined loach.

Diagnosis. Distinguished from other species of *Cobitis* in Balkan Peninsula by: ● zone Z3 absent in juveniles, narrower than zone Z4 in adults, not densely pigmented and not fused with zone Z1 on caudal peduncle / ○ two laminae circularis / ○ 9–15 squarish blotches in zone Z4. Size up to 80 mm SL in females, males smaller.

Distribution. Western Greece: Arachthos drainage.

Habitat. Still to moderately flowing waters with sand to silt, sometimes gravel bottom and vegetation.

Biology. No data.

Conservation status. EN B1 ab(iii) due to small range, habitat alternations and risk of hybridisation with *C. hellenica*.

Further reading. Economidis & Nalbant, 1997: 313 (description).

Cobitis bilineata

Common name. Italian spined loach.

Diagnosis. Distinguished from other species of *Cobitis* in Europe by: ○ two black spots at caudal base / ○ zone Z3 a narrow line of minute spots, usually ending below or in front of dorsal origin in males / ○ zones Z2 and Z4 often continuous dark stripes in mature males / ○ one lamina circularis. Size up to 100 mm SL in females, 65 mm SL in males.

Distribution. Northern Adriatic basin, from Po to Soca drainages (Slovenia, Italy, Switzerland), Durance system (Rhône drainage, France) and Zrmanja drainage (Croatia). Introduced to most of Italy (including Sardinia), Lake Bañolas (northeastern Spain) and upper Rhine drainage (Switzerland).

Habitat. A wide variety of habitats including lakes, rivers, brooks and irrigation channels with still to

Cobitis arachthosensis

Cobitis bilineata

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Cobitis calderoni; Douro drainage, Portugal; ~60 mm SL.

Cobitis dalmatina; Cetina, Croatia; ~45 mm SL.

moderately flowing water. On sand, gravel or mud bottom, often with vegetation.

Biology. Lives up to 4 years. Spawns for the first time at 2 years. Spawns in April – August, in dense vegetation. Females produce 2–7 egg portions per year.

Conservation status. LC.

Further reading. Marconato & Rasotto, 1989 (biology); Bianco, 1994: 465 (distribution); Bohlen, 2000: 182 (reproduction).

Cobitis calderoni

Common name. Lamprehuela.

Diagnosis. Distinguished from other species of *Cobitis* in Iberian Peninsula by: ● lamina circularis absent / ● body depth 9–11 % SL / ● dorsal origin behind or above pelvic origin. Size up to about 100 mm SL in females, 65 mm in males.

Distribution. Iberian Peninsula, in Ebro and Douro drainages, and in some northeastern headwaters of Tagus.

Habitat. Upper and middle reaches of streams with moderate to fast-flowing shallow stretches, well oxygenated, clear water and gravel bottom with few organic material.

Biology. Spawns for the first time at 1 year. Males live up to 2, females to 3 years. Spawns in March – May on gravel bottom. Most likely fractional spawner. Feeds mainly on aquatic invertebrates.

Conservation status. EN A2ace + 3ce due to increased gravel quarrying, habitat destruction and introduction of alien predatory species.

Further reading. Băcescu, 1962: 440 (systematics, habitat); Doadrio, 2001: 216 (biology); Perdices et al., 2000 (genetics); Perdices & Doadrio, 2001: 472 (systematics).

Cobitis dalmatina

Common name. Cetina spined loach.

Diagnosis. Distinguished from other species of

Cobitis calderoni

Cobitis dalmatina

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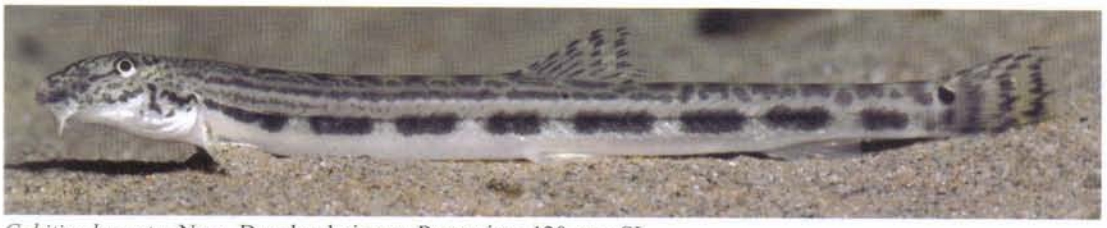


Cobitis elongata; Nera, Danube drainage, Romania; ~120 mm SL.

Cobitis elongatoides; Nera, Danube drainage, Romania; ~70 mm SL.

Cobitis in Northern Adriatic drainages by: ● zone Z2 with large blotches, distinct from zone Z3 and from spots between zones Z1 and Z2 until caudal peduncle / ○ zone Z3 with few spots, narrower than zone Z2 in both sexesf pelvic length / ○ depth of caudal peduncle 1.0–1.7 times in its length. Size up to about 60 mm SL in females, 50 mm SL in males.

Distribution. Croatia: Cetina drainage.

Habitat. In lakes and streams with sand or mud bottom.

Biology. No data.

Conservation status. VU D2.

Further reading. Mrakovčić et al., 2000: 115 (distribution); Schneider et al., 2000b: 233 (diagnosis).

Cobitis elongata

Common name. Balkan spined loach.

Diagnosis. Distinguished from other species of *Cobitis* in Danube drainage by: ● no lamina circularis / ● body depth 10–13 % SL / ○ zone Z2 a continuous narrow line, reaching at least below dorsal base / ○ zone Z3 reaching below dorsal base. Size up to 160 mm SL in females, 90 mm SL in males.

Distribution. Danube drainage: systems of Nera (Romania), Sava, Kupa (Slovenia, Croatia), Morava (Serbia), Vit and Iantra (Bulgaria). Extirpated in Jiu (Romania) and perhaps Iantra (Bulgaria).

Habitat. Moderate to fast-flowing stretches of shallow rivers. On sandy banks and shores, sometimes on rock bottom with submerged vegetation. Not known to enter small streams, large rivers or river stretches without current.

Biology. No data.

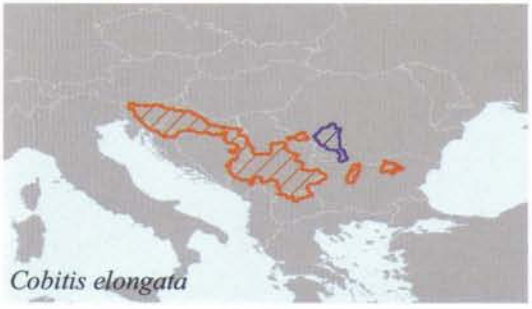
Conservation status. LC. Occurs only as a few restricted populations, most of them apparently stable.

Further reading. Bănărescu & Nalbant, 1957 (description, distribution), 1998 (distribution, conservation).

Cobitis elongatoides

Common name. Danubian spined loach.

Diagnosis. Distinguished from other species of



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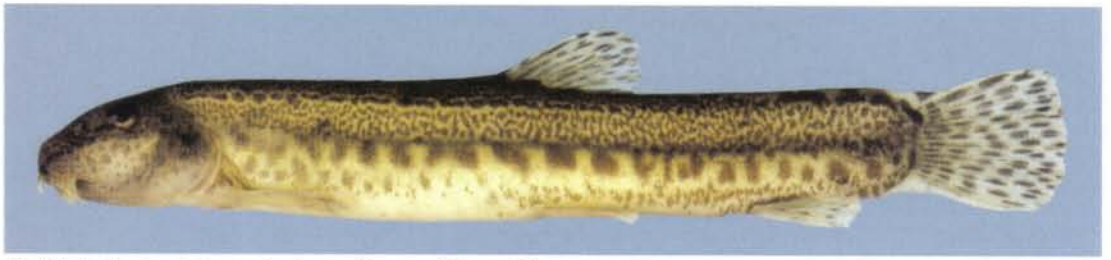

Cobitis hellenica; Louros drainage, Greece; 83 mm SL.

Cobitis in Danube, North Sea and Baltic Sea basins by: ❍ one black spot on upper caudal base about size of eye or pupil, and oval or round / ❍ zone Z3 usually wider than zone Z2 / ❍ zones Z2 and Z3 reaching beyond dorsal base / ❍ one lamina circularis. Size up to 130 mm SL in females, 75 mm SL in males. Not distinguishable from sympatric hybridogenous individuals by external characters.

Distribution. Danube, upper Elbe and Odra drainages.

Habitat. Flowing or still waters from small brooks to large rivers, springs, lakes and oxbows. On sand, silt or mud bottom.

Biology. Females live up to 5 years, males up to 3 years. Spawns in aquatic vegetation in April – July. Usually occurring together with hybridogenous, sperm-parasitic lineages, which have originated by hybridisation with *C. taenia* and *C. tanaitica*.

Conservation status. LC.

Remarks. Distinguished from *C. vardarensis* and *C. pontica* only by chromosome characters. They cannot be distinguished in the field.

Further reading. Nalbant, 1993: 109 (description, as *C. taenia danubialis*); Kottelat, 1997: 88 (nomenclature); Freyhof et al., 2000: 4 (systematics); Janko et al., 2003 (hybrids).

Cobitis hellenica

Common name. Louros spined loach.

Diagnosis. Distinguished from other species of *Cobitis* in Balkan Peninsula by: ❍ zone Z4 with 12–18 blotches, often squarish, triangular, or fused two by two / ❍ two laminae circularis / ❍ flank pigmented below zone Z4 / ❍ zone Z3 present in juveniles, in large adults (over 70 mm SL) wider than zone Z4, densely pigmented and fused with zone Z1 on caudal peduncle. Size up to 90 mm SL in females, males smaller.

Distribution. Western Greece: Louros and Kalamas drainages.

Habitat. Still to moderately flowing, clear waters of streams with dense vegetation on sand to silt bottom.

Biology. No data.

Conservation status. EN B1ab(iii,v) + 2ab(iii,v).

Further reading. Economidis & Nalbant, 1997: 311 (description).

Cobitis illyrica

Common name. Imotzki spined loach.

Diagnosis. Distinguished from other species of *Cobitis* in northern Adriatic drainages by: ❍ single, indistinct black spot at upper caudal base or no black spot / ❍ postdorsal blotches 1–3 roundish, with convex lateral margins / ❍ zone Z1 indistinct, with few small spots, narrower than zone Z2 / ❍ in front of dorsal, zone Z3 formed by few dots in males, narrower or as wide as zone Z2 / ❍ behind dorsal, zones Z1–Z3 confluent in males / ❍ distance between tip of pectoral and origin of pelvic origin 70–80 % of pelvic length / ❍ depth of caudal peduncle 1.9–2.3 times in its length. Size up to 64 mm SL, most likely larger.

Distribution. Croatia: Imotzki polje.

Habitat. Still waters of lakes on mud bottom.

Biology. No data.

Conservation status. CR B1ab(ii,iii).

Cobitis hellenica

Cobitis illyrica

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Cobitis illyrica; Imotzki polje, Croatia; 65 mm SL. J. Bohlen

Cobitis melanoleuca; Kuban drainage, Russia; ~90 mm SL.

Further reading. Freyhof & Stelbrink, 2007 (description).

Cobitis melanoleuca

Common name. Siberian spined loach.

Diagnosis. Distinguished from other species of *Cobitis* in European Russia by: ● two black spots on caudal base, lower one sometimes weak. Size up to 110 mm SL in females, 75 mm SL in males.

Distribution. Don, Kuban, Volga, Ural and Eya drainages. Outside Europe in most Siberian drainages, eastward to Amur and Huang He (China).

Habitat. From small lowland streams to large rivers with gentle current, and lakes. Mostly in habitats with dense vegetation on sand-silt to sand-gravel bottom.

Biology. Spawns in May – June, when temperatures reach 16–17°C, among filamentous algae or other aquatic vegetation.

Conservation status. LC.

Remarks. *C. granoei* and *C. sibirica* are synonyms.

Further reading. Rendahl, 1935: 322 (description); Vasilieva, 1984: 45 (morphology); Vasiliev et al., 1989: 159 (biology); Nalbant, 1993 (systematics).

Cobitis meridionalis

Common name. Prespa spined loach.

Diagnosis. Distinguished from other species of *Cobitis* in Balkan Peninsula by: ● blotches of zones Z2 and Z4 grey to olive, edges not sharply contrasted / ● zones Z1 and Z3 absent or very poorly defined and present only on anterior half of body / ○ two laminae circularis. Size up to 110 mm SL in females, 70 mm SL in males.

Distribution. Lakes Prespa (Greece, Macedonia, Albania).

Habitat. Lake shores and streams with sand or mud bottom and underwater vegetation.

Biology. Lives only one year and grows very fast, reaching 60 mm SL after 130 days, growing from May to October, when temperature is above 10°C. Spawns in late April – May. Probably a multiple

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Cobitis meridionalis; Lake Megali Prespa, Greece; 84 mm SL.

Cobitis narentana; Neretva, Bosnia-Herzegovina; ~75 mm SL.

spawner.
Conservation status. VU D2.
Further reading. Economidis & Nalbant, 1997: 308 (description); Crivelli & Lee, 2000 (biology).

Cobitis narentana

Common name. Neretva spined loach.
Diagnosis. Distinguished from other species of *Cobitis* in Adriatic drainages by: ❍ single, conspicuous, comma-shaped black spot at upper caudal base / ❍ postdorsal blotches 1–3 squarish, with straight or concave lateral margins / ❍ depth of caudal peduncle 1.3–1.9 times in its length. Size up to 90 mm SL in females, 60 mm SL in males.
Distribution. Neretva and Trebisnjica drainages (Croatia, Bosnia-Herzegovina).
Habitat. Lakes and river shores on sand bottom.
Biology. Males live up to 3 years, females up to 5. Males reproduce for the first time at about 40 mm SL. In some localities, sex-ratio female-biased. Fractional spawner, spawns 2–3 times in April – August.
Conservation status. VU D2. Threatened by construction of Neretva dam and introduced species.
Remarks. *Cobitis* populations in Jadova polje and in Mostarsko Blato in Croatia and Bosnia-Herzegovina may represent unnamed species.
Further reading. Mrakovčić et al., 2000: 115 (distribution, conservation); Schneider et al., 2000a: 159 (biology), 2000b: 233 (diagnosis).

Cobitis ohridana

Common name. Ohrid spined loach.
Diagnosis. Distinguished from other species of *Cobitis* in Balkan Peninsula by: ❍ dark spot on upper caudal base often small, faint or missing / ❍ zone Z3 narrower than zone Z2, comprising a single row of small dots / ❍ one lamina circularis. Size up to at least 65 mm SL in females, males smaller.
Distribution. From Drin to Aoos drainages (Albania, Macedonia, Serbia, Greece), including lakes Ohrid and Skadar.
Habitat. Rivers and lakes, over fine to muddy sand and among algae.
Biology. No data.
Conservation status. LC.
Further reading. Karaman, 1929: 173 (description).

Cobitis paludica

Common name. Colmilleja.
Diagnosis. Distinguished from other species of *Cobitis* in Iberian Peninsula by: ❍ mandibular bar-

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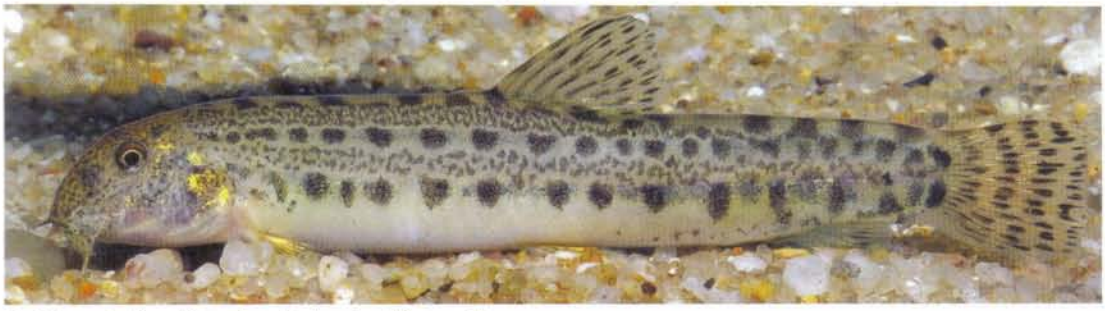
Cobitis ohridana; Moraca, Drin drainage, Montenegro; ~60 mm SL.



Cobitis paludica; Sizandro, Portugal; ~80 mm SL.

Cobitis paludica; Guardiana drainage, Spain; ~70 mm SL.

bel 4–8 times in HL / ♂ pectoral fin length 4.3–5.4 times in SL in males, 4.3–9.0 times in females / ♂ 6–7½ branched dorsal rays / ♂ one lamina circularis. Size up to 130 mm SL in females, 70 mm SL in males.

Distribution. Most of Iberian Peninsula, except in Alagon system (Tagus drainage), northern Ebro and northern Douro drainages, and northward (where it has been locally introduced).

Habitat. Quiet stretches with sand or mud bottom and stones, wood or aquatic vegetation. Usually in middle to lower stretches of rivers and streams.

Biology. Males live up to 4 years, females up to 5. Spawns for the first time at 1 year. Spawns in April – July. Fractional spawner producing several portions per season. Eggs small (1.7 mm) and sticky, placed within dense vegetation if available. Sur-

Cobitis ohridana

Cobitis paludica

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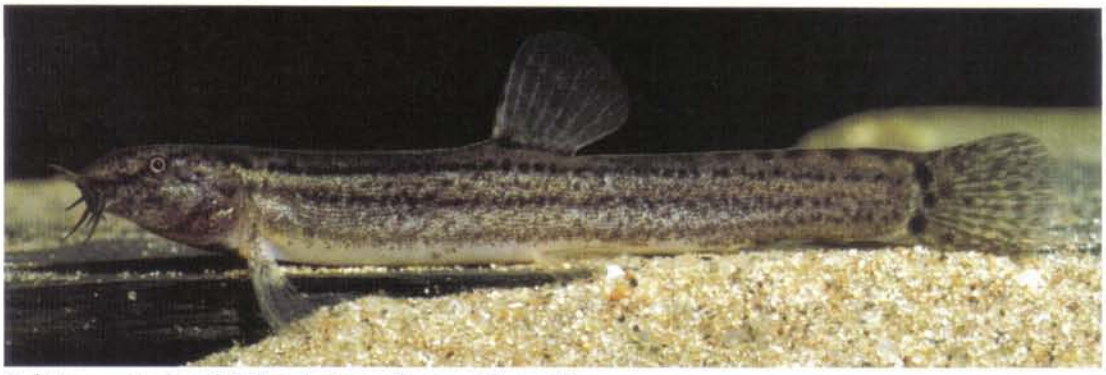
Cobitis pontica; Lake Sapanca, Turkey; ~60 mm SL.



Cobitis puncticulata; Maritza drainage, Greece; 59 mm SL.

vives dry periods in very small water bodies. Feeds predominantly on small invertebrates.
Conservation status. VU A2ce + 3ce.
Remarks. *C. victoriae* is a synonym.
Further reading. Băcescu, 1962 (description; as *C. paludicola*); Doadrio, 2001: 218 (biology); Perdices & Doadrio, 1997: 360 (conservation); Przybylski & Valladolid, 2000 (biology); Bohlen, 2000: 182 (reproduction); Oliva-Paterna et al., 2002 (reproduction).

Cobitis pontica

Common name. Istanca spined loach.
Diagnosis. Distinguished from other species of *Cobitis* in Black Sea basin by: O one black spot on upper caudal base, about eye-size and oval or round / O zone Z3 usually wider than zone Z2 / O zones Z2 and Z3 reaching backwards beyond dorsal base / O one lamina circularis. Size up to 100 mm SL.
Distribution. From Veleka (Bulgaria) to Istanca (Turkish Thrace) drainages; Marmara Sea basin and lower Sakarya drainage (Anatolia).
Habitat. Flowing or still waters, from small brooks to large rivers. On sand, silt or mud bottom.
Biology. No data.
Conservation status. LC.
Remarks. Earlier identified as *C. vardarensis*. Distinguished from *C. vardarensis* and *C. elongatoides* only by chromosome characters. They cannot be distinguished in the field, except by origin.

Cobitis pontica

Cobitis puncticulata

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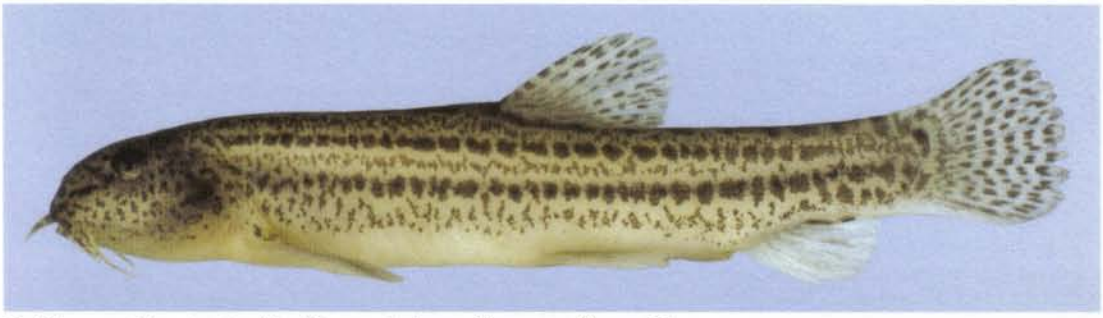

Cobitis punctilineata; Angitis, Struma drainage, Greece; ~65 mm SL.

Cobitis punctilineata; Angitis, Struma drainage, Greece; ~60 mm SL.

Further reading. Erk'akan et al., 1998: 12 (description; as *C. vardarensis*); Vasilieva & Vasiliev, 2006: S17 (description).

Cobitis puncticulata

Common name. Brown spined loach.
Diagnosis. Distinguished from other species of *Cobitis* in Balkan Peninsula by: ● body brownish / ● blotches of zone Z2 and Z4 very small, indistinct or confluent / ○ flank pigmented below zone Z4 / ○ one lamina circularis. Size up to 78 mm SL in females, males smaller.
Distribution. Greece: lower Maritza drainage; Turkey: Lakes Manyas and Ulubat drainages, most likely wider distribution.
Habitat. Streams with still to moderately flowing clear water and mud bottom.
Biology. No data.
Conservation status. CR B1ab(iii) + 2ab(iii).
Further reading. Erk'akan et al., 1998: 12 (description).

Cobitis punctilineata

Common name. Aggitis spined loach.
Diagnosis. Distinguished from other species of *Cobitis* in Balkan Peninsula by: ● lateral spots small, roundish and numerous (usually more than 40) / ○ flank pigmented below zone Z4 / ○ two laminae circularis. Size up to 100 mm SL in females, males smaller.
Distribution. Greece: Aggitis system (Struma drainage).
Habitat. Streams, channels and springs with still to moderately flowing clear shallow water and mud to silt bottom.
Biology. No data.
Conservation status. VU D2; very restricted area of occurrence.
Further reading. Economidis & Nalbant, 1997: 314 (description).

Cobitis stephanidisi

Common name. Velestino spined loach.
Diagnosis. Distinguished from other species of *Cobitis* in Balkan Peninsula by: ● zone Z4 forming a continuous black or grey stripe / ○ flank pigmented below zone Z4 / ○ one lamina circularis. Size up to 90 mm SL in females, males smaller.
Distribution. Greece: karstic springs Kefalovriso (Velestino) and Chasambali (Pinios drainage, Thessaly).
Habitat. Clear, still or slowly flowing water with

Cobitis punctilineata

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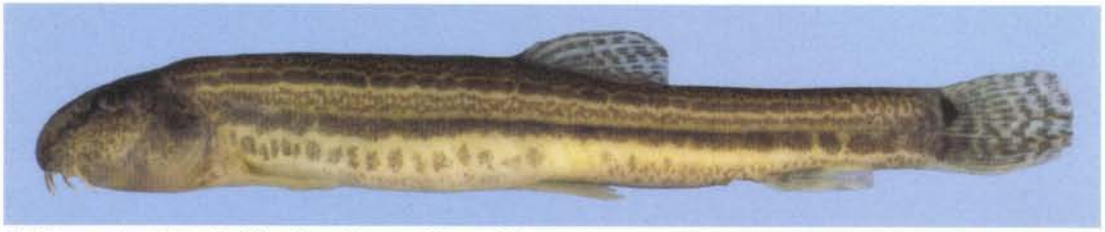

Cobitis stephanidisi; Kefalovriso, Greece; 70 mm SL.

Cobitis strumicae; Provadiskaya, Bulgaria; ~70 mm SL.

silt bottom and underwater vegetation.
Biology. No data.
Conservation status. CR B1ab(i,ii,iii,v) + 2ab (i,ii,iii,v). Originally known only from Velestino, from where extirpated in 1998. Rediscovered in 2001 in Chasambali.
Further reading. Economidis & Nalbant, 1997: 303 (description).

Cobitis strumicae

Common name. Struma spined loach.
Diagnosis. Distinguished from other species of *Cobitis* in Balkan Peninsula by: ✪ black spot at caudal base, very small or sometimes absent, rarely two small spots / ✪ zone Z4 with 12–21 roundish or squarish blotches, sometimes indistinct or fused two by two / ✪ flank not pigmented below zone Z4 / ✪ two laminae circularis. Size up to 110 mm SL in females, 75 mm SL in males.
Distribution. Aegean and Black Sea basins, from Struma drainage to area of Varna (Greece, Bulgaria, Turkey), Lakes Volvi and Koronia (Greece); Danube basin in Bulgaria.
Habitat. Still to flowing waters with sand or silt bottom.
Biology. No data.
Conservation status. LC.
Remarks. *C. peschevi* and *C. rhodopensis* are synonyms. In Danube and Struma drainage, occurs together with hybridogenous, sperm-parasitic lineages, which have originated by hybridisation of *C. elongatoides* with *C. taenia* or *C. tanaitica*.
Further reading. Economidis & Nalbant, 1997: 305 (description); Ivanova & Dobrovolov, 2002 (morphology, biochemistry); Kottelat & Freyhof, 2007b (nomenclature).

Cobitis taenia

Common name. Northern spined loach.
Diagnosis. Distinguished from other species of *Cobitis* in Atlantic, Baltic, North and Black Sea basins by: ✪ single small spot on upper caudal base / ✪ zones Z1-Z4 usually well differentiated, extending backward to caudal peduncle / ✪ height of blotches of zone Z4 usually less than 2 times in their length; if more than 2 times, then height equal to or greater than horizontal eye diameter / ✪ one lamina circularis. Size up to 95 mm SL in females,

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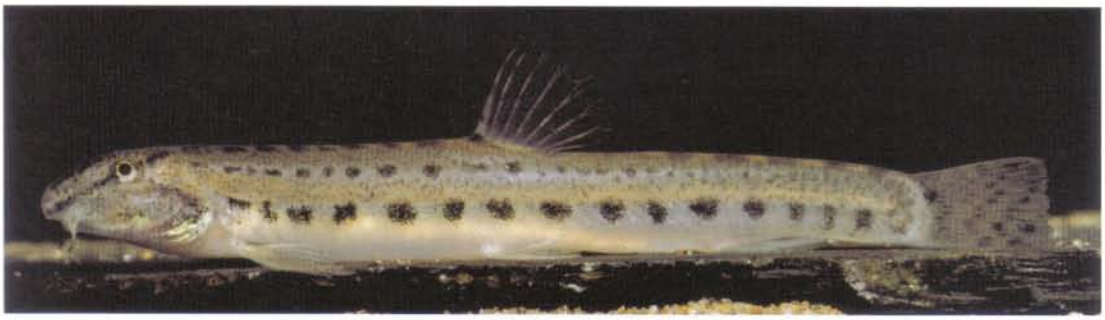

Cobitis taenia; lower Odra drainage, Germany; ~60 mm SL.

Cobitis tanaitica; Lower Kuban, Russia; ~65 mm SL.

70 mm SL in males. Not or difficultly distinguishable from sympatric hybridogenous individuals by external characters.

Distribution. Atlantic drainages from Loire northward; Baltic basin south of 61°N; upper Volga and Ural drainages; northern Black Sea basin (except Danube). Ancient records from Adour and Garonne drainages (France) require confirmation.

Habitat. From small lowland streams to large rivers. In channels, ditches, backwaters and lakes on sand bottom. In Baltic Sea at salinity up to 5 ‰.

Biology. Females live up to 5 years, males up to 3. Females spawn for the first time at 2–3 years, males at 1–2 years and more than 45 mm SL. Spawns in April – July, at temperatures above 18°C. Eggs are spawned in dense vegetation. Fractional spawner, producing 1–18 portions (under laboratory conditions). Larvae negatively phototactic, hiding under vegetation and in debris until beginning of exogenous feeding. Usually occurring together with hybridogenous, sperm-parasitic lineages, which have originated by hybridisation with *C. elongatoides* or *C. tanaitica*.

Conservation status. LC.

Further reading. Robotham, 1978, 1981, 1982 (biology); Kottelat, 1997: 89 (systematics); Freyhof et al., 2000: 3 (systematics); Bohlen, 2000, 2003 (reproduction); Janko et al., 2003 (hybrids).

Cobitis tanaitica

Common name. Don spined loach.

Diagnosis. Distinguished from other species of *Cobitis* in Central Europe and Black Sea basin by: ○ zone Z3 usually ending under dorsal base in male / ○ one black spot at caudal base, about size of pupil or eye, oval or round / ○ zone Z3 usually narrower than zone Z2 / ○ one lamina circularis. Size up to 95 mm SL in females, 60 mm SL in males. Not distinguishable from sympatric hybridogenous individuals by external characters.

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Cobitis taurica; Chornaya, Crimea, Ukraine; male, ~60 mm SL.

Cobitis trichonica; Lake Trichonis, Greece; 72 mm SL.

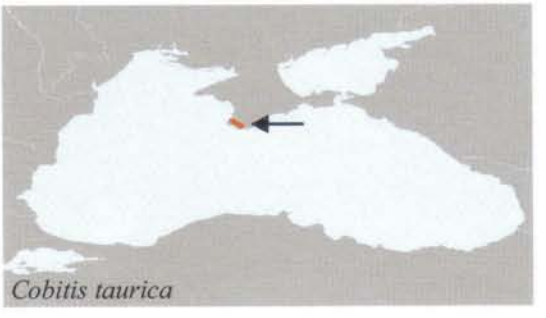
Distribution. Northern and western Black Sea basin (from Danube to Kuban drainages). In Danube, Dniestr and Kuban drainages restricted to lowermost part. More widespread in South Bug and Dniepr drainages. Expected in part of Baltic basin (Vistula and Odra drainages).
Habitat. Large coastal lakes and lower part of rivers on silt bottom, as well as smaller streams with sand bottom.
Biology. Spawns in May. Migrates to larger water bodies in autumn for overwintering. Usually occurring together with hybridogenous, sperm-parasitic lineages, which have originated by hybridisation with *C. elongatoides* or *C. taenia*.
Conservation status. LC.
Remarks. *C. rossomeridionalis* is a synonym.

Chornaya, southern Crimea, Ukraine; habitat of the endemics *Cobitis taurica*, *Gobio delyamurei*, *Proterorhinus tataricus* and of the Crimean endemics *Barbus tauricus* and *Alburnus mentoides*.

Further reading. Vasilieva & Vasiliev, 1998 (distribution, description, biology); Freyhof et al., 2000: 5 (systematics); Vasilieva, 2000: 24 (genetics); Janko et al., 2003 (hybrids).

Cobitis taurica

Common name. Crimean spined loach.
Diagnosis. Distinguished from other species of *Cobitis* in Central Europe and Black Sea basin by: ○ single small spot on upper caudal base / ○ height of blotches of zone Z4 usually 2 times in their length, less than horizontal eye diameter / ○ one lamina circularis. Size up to 92 mm SL in females, 60 mm SL in males.
Distribution. Ukraine: Crimea: Chornaya drainage.
Habitat. Streams with still to moderately flowing clear water, on sand to silt bottom or in dense vegetation.
Biology. No data.



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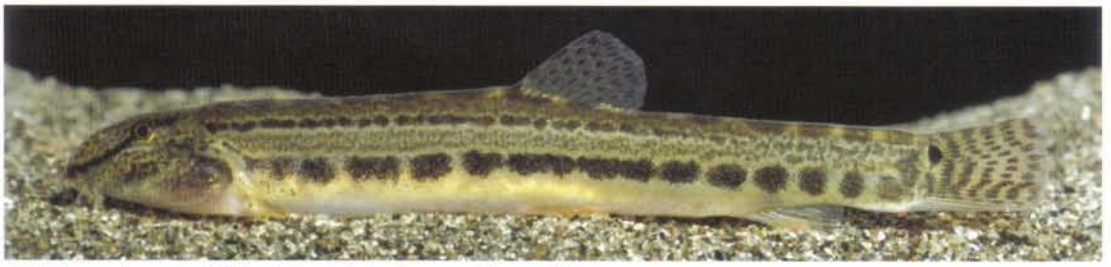

Cobitis vardarensis; Pinios (Thessaly), Greece; 60 mm SL.

Conservation status. CR B1ab(ii,iii) + 2ab (ii,iii)*. Still abundant in a very limited stretch of stream, but declining. If water abstraction intensifies, the whole steam might dry in summer.
Remarks. This species is mainly distinguished by chromosome characters and difficult to distinguish from C. *taenia* in the field. Characters given in the key may be of limited use. A population with similar chromosomes characters is known from lower South Bug (Ukraine); it might represent an unnamed species.
Further reading. Vasilieva, 1984 (morphology); Janko et al., 2005 (description).

Cobitis trichonica

Common name. Trichonis spined loach.
Diagnosis. Distinguished from other species of *Cobitis* in Balkan Peninsula by: ● zone Z4 with 9–14 large blotches, those on caudal peduncle mostly vertically elongated, sometimes fused into a midlateral stripe in males / ○ axial streak conspicuous along upper margin of blotches of zone Z4 / ○ two laminae circularis. Size up to 80 mm SL in females, 55 mm SL in males.
Distribution. Greece: Acheloos drainage.
Habitat. Lakes, channels and streams with still to moderately flowing clear water, on sand to silt bottom or in dense vegetation.
Biology. Spawns in April – June. Multiple spawner.
Conservation status. EN B1ab(iii) + 2ab(iii).
Further reading. Stephanidis, 1974a (description); Economidis & Nalbant, 1997: 309 (description); Economou et al., 1994a: 30 (reproduction, larvae).

Cobitis vardarensis

Common name. Vardar spined loach.
Diagnosis. Distinguished from other species of *Cobitis* in Balkan Peninsula by: ○ zone Z4 with 13–24 well separated spots / ○ zone Z3 wider than zone Z2, comprising several rows of small dots / ○ dark spot at caudal base clearly visible / ○ one lamina circularis. Size up to 90 mm SL in females, males smaller.
Distribution. Aegean Sea basin, from Pinios to Gallikos drainages (Greece, Macedonia).
Habitat. Still waters of lakes, oxbows and backwaters, rarely in flowing water. On mud to silt bottom.
Biology. No data.
Conservation status. LC.
Remarks. Distinguished from *C. elongatoides* and *C. pontica* only by chromosome characters. They cannot be distinguished in the field, except by origin.
Further reading. Economidis & Nalbant, 1997: 301 (description).

Cobitis vettonica

Common name. Alagon spined loach.
Diagnosis. Distinguished from other species of *Cobitis* in Iberian Peninsula by: ● all barbels very small, hardly visible, mandibular barbel 7–40 times in HL / ○ pectoral fin length 4.9–8.6 times in SL in males, 6.9–13.5 times in females / ○ 7½ branched dorsal rays / ○ one lamina circularis. Size up to 90 mm SL in females, 60 mm SL in males.
Distribution. Spain: Alagón system (Tagus drainage).

Cobitis trichonica

Cobitis vardarensis

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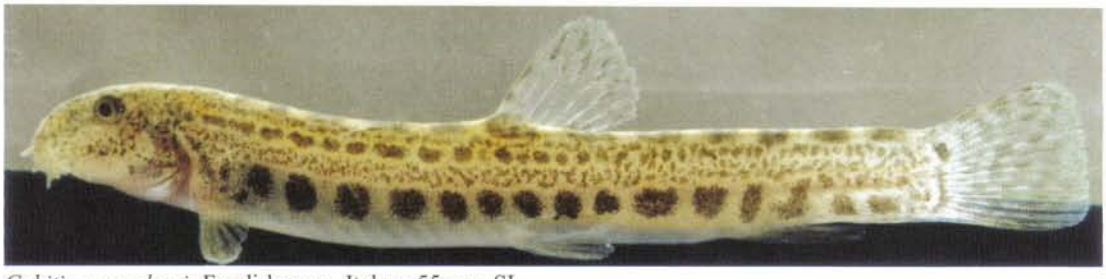
Cobitis vettonica; Alagon, Spain; ~70 mm SL.



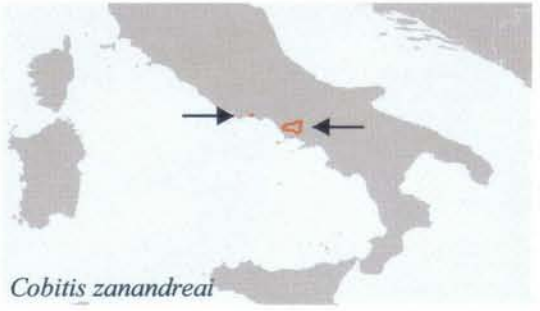
Cobitis zanandreai; Fondi lagoon, Italy; ~55 mm SL.

Habitat. In deep, large streams with clear water, and sand to rock bottom.
Biology. Spawns in April – June.
Conservation status. EN B1ab(ii,iii,v)+ 2ab(ii, iii,v); very restricted area of occurrence, agricultural water pollution, drought and introduced predators.
Remarks. This species is mainly distinguished by mtDNA characters and difficult to distinguish from C. *paludica* in the field. Characters given in the key may be of limited use.
Further reading. Doadrio & Perdices, 1997: 53 (description); Carmona et al., 1999: 377 (habitat); Doadrio, 2001: 220 (distribution).

Cobitis zanandreai

Common name. Volturno spined loach.
Diagnosis. Distinguished from other species of *Cobitis* in Italy by: ● zone Z4 not reaching caudal base, replaced by irregular spots, indistinguishable from those of zones Z2 and Z3 immediately in front of caudal / ● small black spot on upper caudal base often barely visible / ○ depth of caudal peduncle about 1.3 times in its length. Size up to 75 mm SL in females, 60 mm SL in males.
Distribution. Southern Italy: Volturno drainage near Caserta and Fondi lagoon.
Habitat. Stream with sand bottom, drainage channels and irrigation ponds; lacustrine.
Biology. No data.
Conservation status. VU D2; due to very restricted area of occurrence, habitat alteration and changes of land-use.
Further reading. Cavicchioli, 1965: 1152 (description); Perdices & Doadrio, 2001: 472 (genetics).

Cobitis vettonica



Cobitis zanandreai

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Key to species of *Misgurnus* and *Paramisgurnus* in Europe

Misgurnus fossilis is native to Europe; *M. anguillicaudatus* and *Paramisgurnus dabryanus* are regularly imported from southern China as ornamental species for garden ponds. *Misgurnus anguillicaudatus* is locally established in Germany and Italy, and it is possible that *P. dabryanus* too, has escaped in European waters. The key allows the identification of all three species.

1a – Broad midlateral stripe from eye to caudal base and narrow stripe from opercle at least to pelvic origin; lamina circularis absent in male.
..... *M. fossilis*

1b – Dark, irregular spots on body; lamina circularis present in male.
..... 2

2a – Caudal peduncle with low adipose crests; lamina circularis roundish with smooth posterior margin; dark spot at upper caudal base.
..... *M. anguillicaudatus*

2b – Caudal peduncle with high adipose crests; lamina circularis spade-shaped with crenulated posterior margin; no dark spot at upper caudal base.
..... *P. dabryanus*

Misgurnus anguillicaudatus

Common name. Asian weather loach.

Diagnosis. Distinguished from other species of *Misgurnus* potentially present in Europe by: ○ dark, irregular spots on body, no stripes / ○ caudal peduncle with low adipose crests / ● lamina circularis present in male, roundish, with smooth posterior margin / ● dark spot at upper caudal base. Size up to about 280 mm SL.

Distribution. Native to Siberia (Tugur and Amur drainages), Sakhalin, Korea, Japan, China south to northern Vietnam. Introduced in several localities in Rhine (Germany) and Ticino (Italy, north of Milano) drainages, Aral Sea basin, North America, Australia and Hawaii.

Habitat. In Asia, inhabits a wide range of habitats, lakes, ponds, rivers and streams. In Europe known from a few isolated ponds.

Biology. Biology of introduced populations unknown. Able to survive in habitats with low oxygen concentrations by cutaneous and intestinal respiration.

Conservation status. Alien.

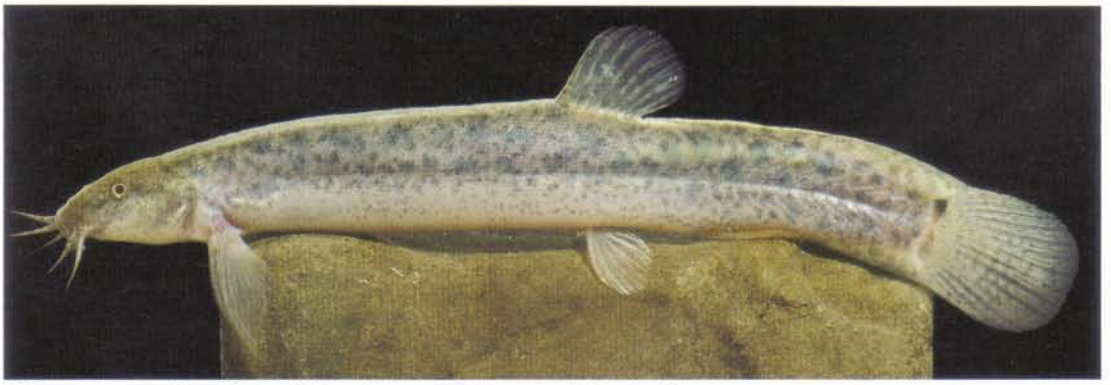
Further reading. Vasilieva, 2001 (systematics); Razzetti et al., 2001 (introduction to Italy); Freyhof & Korte, 2005 (introduction to Germany).

Misgurnus fossilis

Common name. Weather loach.

Diagnosis. Distinguished from other species of *Misgurnus* in Europe by: ● broad midlateral stripe from eye to caudal base and narrow stripe from opercle at least to pelvic origin / ● lamina circularis absent in males. Size up to 270 mm SL.

Distribution. Europe north of the Alps, from Meuse eastward to Neva drainages and Lake Ladoga; northern Black Sea basin from Danube eastward to Kuban; Caspian basin in Volga and Ural drainages. In Black Sea basin, absent south of Danube and Kuban. Not native to Great Britain, Scandinavia, Apennine and Iberian Peninsulas, Crimea, and Adriatic, Aegean and White Sea



Misgurnus anguillicaudatus; Rhine drainage, Germany; ~150 mm SL.

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Misgurnus fossilis; Trave drainage, Germany; ~160 mm SL.

Misgurnus fossilis; Danube drainage, Germany, male, left, and female, right; ~200 mm SL. A. Hartl

basins. Locally introduced in Rhône drainage (France) and perhaps elsewhere.

Habitat. Backwaters and side channels of lowland streams, rivers and lakes. Mostly restricted to densely vegetated habitats with slow or no current and soft, mud bottom. Spawns in dense vegetation, often in flooded meadows.

Biology. Spawns for the first time at 2–3 years, at about 110 mm SL. Spawns in March – July at temperatures above 19°C. Males have a larger second pectoral ray and shallow vertical swellings of flanks above anal base, enlarged during spawning time. Male follows female into dense vegetation and forms a complete ring around her body, behind dorsal fin. Sticky eggs are released into vegetation. Larvae move to bottom and hide in vegetation. Larvae have large external gill filaments, resorbed after 10–12 days. Adults nocturnal, burrow into mud during dry periods and strong frosts. Usually burrows 200–300 mm deep, occasionally down to 700 mm during dry periods. Able to survive in habitats with low oxygen concentrations by cutaneous and intestinal respiration. Frequently swallows air, oxygen being absorbed through the walls of the gut. Feeds on benthic invertebrates. Swims slowly above bottom and dig for invertebrates, which are localized by olfaction.

Conservation status. LC. Gradual but continuing extirpation in many water bodies.

Further reading. Fusko, 1987 (biology).

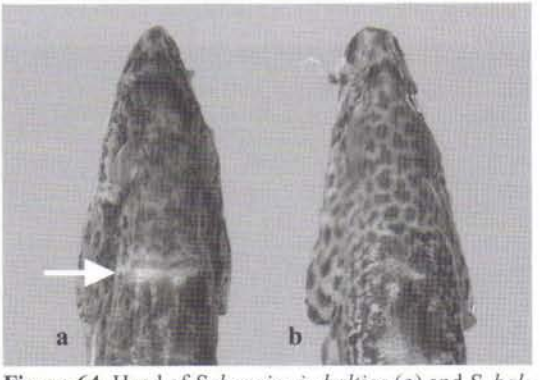

Figure 64 Head of *Sabanejewia baltica* (**a**) and *S. balcanica* (**b**), to show narrow whitish saddle behind head (arrow).

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Key to species of *Sabanejewia*

Sabanejewia aurata and *S. caspia* from Caspian basin are not recorded from European waters. Their presence cannot be totally ruled out and both are included in the key.

1a – Marbled pigmentation or lines along flank, not forming a midlateral row of dark blotches. 2

1b – A midlateral row of dark lathe blotches along flank. 3

2a – A narrow continuous dark brown streak along flank; no large dorsal blotches; anterior branch of suborbital spine much shorter than posterior branch. ..... *S. caspia*

2b – Marbled pigmentation along flank not forming a streak; dark blotches on dorsum, often fused; branches of suborbital spine of similar length. ..... *S. caucasica*

3a – A fine black line along flank, running through midlateral blotches. ..... *S. romanica*

3b – No black line along flank. 4

4a – A row of 15–27 midlateral blotches, often fused into an irregular stripe; ventral and dorsal adipose crests on caudal peduncle similarly developed; a dark spot on lower lip; at least one row of spots directly below midlateral blotches. ..... *S. larvata*

4b – A row of 4–18 midlateral blotches; ventral adipose crest on caudal peduncle absent or less developed than dorsal one; no dark spot on lower lip; no row of small spots directly below midlateral blotches (if present, then most prominent between pelvic and anal bases). 5

5a – Dorsal origin behind pelvic origin. ..... *S. aurata*

5b – Dorsal origin above or in front of pelvic origin. 6

6a – Dorsal origin in front of pelvic origin. 7

6b – Dorsal origin above pelvic origin. 9

7a – Distance between the two black spots at caudal base greater than their diameter. ..... *S. vallachica*

7b – Distance between the two black spots at caudal base much less than their diameter. 8

8a – Interspaces between midlateral blotches usually with dark pigmentation; if interspaces with little or no dark pigmentation, narrow whitish saddle behind head without dark spots (Fig. 64); dorsal origin above or in front of pelvic origin; mature adults usually about 60–90 mm SL. ..... *S. baltica*

8b – Interspaces between midlateral blotches with very little or no dark pigment; narrow whitish saddle behind head with dark spots; dorsal origin always in front of pelvic origin; mature adults usually about 50–60 mm SL. ..... *S. kubanica*

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9a – Interspaces between midlateral blotches usually with dark pigmentation, many individuals with uniform dark lateral coloration; body above midlateral blotches uniform brown or with small whitish to yellowish spots or speckles.
..... *S. baltica*

9b – Interspaces between midlateral blotches without dark pigmentation; body above midlateral blotches brown with whitish to yellowish marbling or vermiculations, or with a few dark blotches, or unpigmented.
..... 10

10a – A row of 4–9, rarely up to 10 midlateral blotches; 5–8, rarely up to 10 dorsal blotches; body above midlateral blotches with a few dark spots or unpigmented; body depth 16.5–20 % SL.
..... *S. bulgarica*

10b – A row of 10–17, rarely 8–9 midlateral blotches; 10–17, rarely 8–9 dorsal blotches; body above midlateral blotches brown with whitish to yellowish marbling or vermiculations; body depth 12–18 % SL.
..... *S. balcanica*

Sabanejewia balcanica

Common name. Balkan golden loach.

Diagnosis. Distinguished from other species of *Sabanejewia* in Europe by: ○ a midlateral row of 10–17 (rarely 8–9) dark blotches along flank / ○ ventral adipose crest on caudal peduncle absent or less developed than dorsal one / ○ no row of small spots directly below midlateral blotches (if present, then most prominent between pelvic and anal bases) / ○ dorsal origin above pelvic origin / ○ interspaces between midlateral blotches without dark pigmentation / ○ body above midlateral blotches brown with whitish to yellowish marbling or vermiculations / ○ 10–17, rarely 8–9 dorsal blotches / ○ body depth 12–18 % SL. Size up to 90 mm SL.

Distribution. Black Sea basin, in Danube drainage; Aegean Sea basin, in Maritza and from Gallikos to Pinios drainages.

Habitat. Mainly hill streams with clear water and bottom with sand or fine gravel bottom. In moderate current with few plants at water depths up to 1.5 m. Also observed in large rivers.

Biology. Burrows during daylight into sand, sometimes in gravel. Spawns in spring. In aquarium, eggs indiscriminately scattered over sand, gravel and plants. A dwarf population was observed in a pond fed by a warm thermal spring with constant temperature in western Romania.

Conservation status. LC. Locally threatened by habitat alterations.

Remarks. Populations (even from close localities) exhibit important differences in pigmentation pattern, morphology and habitat. Although this variability lead to the recognition of several populations as distinct taxa, we treat the Danubian and Balkan populations as a single species; however, this requires critical re-examination.

Further reading. Bănărescu et al., 1972: 3 (description); Ahnelt & Tiefenbach, 1994: 11 (biology); Kottelat, 1997: 90 (systematics).

Sabanejewia baltica

Common name. Northern golden loach.

Diagnosis. Distinguished from other species of *Sabanejewia* in Europe by: ○ a midlateral row of dark blotches along flank / ○ ventral adipose crest on caudal peduncle absent or less developed than dorsal one / ○ no row of small spots directly below midlateral blotches (if present, then most prominent between pelvic and anal bases) / ○ dorsal origin above or in front of pelvic origin / ○ distance between the two black spots at caudal base much less than their diameter / ○ interspaces between midlateral blotches usually with dark pigmentation (if there is little or no dark pigmenta-

Sabanejewia balcanica

Sabanejewia baltica

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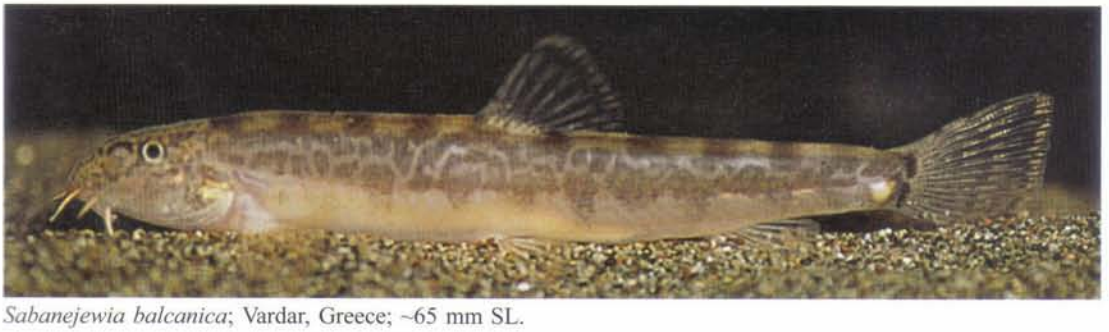
Sabanejewia balcanica; Danube, Hungary; ~55 mm SL.

Sabanejewia balcanica; Mureş, Danube drainage, Romania; ~70 mm SL.

Sabanejewia balcanica; Maritza, Greece; ~60 mm SL.



Sabanejewia balcanica; Vardar, Greece; ~65 mm SL.

tion, then no dark spots in narrow whitish saddle behind head; Fig. 64) / ○ body above midlateral blotches uniform brown or with small whitish to yellowish spots or speckles / ○ mature adults usually about 60–90 mm SL / ● body coloration often almost plain grey or brown. Size up to 90 mm SL.

Distribution. Black Sea basin, in Dniestr, Dniepr and Don drainages; Baltic basin, in Vistula and Odra drainages.

Habitat. Inhabits a wide range of habitats from small lowland streams to fast-flowing piedmont rivers with clear water and sand to gravel bottom. Usually absent from large lowland rivers.

Biology. Burrows into sand, avoids mud or silt,

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Sabanejewia baltica; Upper Dniestr drainage, Ukraine; ~70 mm SL.

Sabanejewia baltica; Upper Dniepr drainage, Ukraine; ~70 mm SL.

sometimes in gravel. Spawns in spring. Eggs 1.1–1.2 mm in diameter, sticky and indiscriminately scattered over sand, gravel or other structures. Portion spawner. Eggs hatch in 50–60 h at 22°C. Larvae 3.1–4.2 mm TL start to feed after 6 days. Free larvae lack external gill filaments, but have a prominent transparent bump on forehead.

Conservation status. LC. Rare and known from scattered populations in Baltic basin and Dniepr. Abundant and widespread in Dniestr.

Further reading. Witkowski, 1994 (description); Bohlen, 2000 (reproduction); Perdices et al., 2003 (genetics).

Sabanejewia bulgarica

Common name. Bulgarian golden loach.

Diagnosis. Distinguished from other species of *Sabanejewia* in Europe by: ○ a midlateral row of 4–9 (rarely up to 10) dark blotches along flank / ○ ventral adipose crest on caudal peduncle absent or less developed than dorsal one / ○ no row of small spots directly below midlateral blotches / ○ dorsal origin above pelvic origin / ○ interspaces between midlateral blotches without dark pigmentation / ● body above midlateral blotches with a few dark spots or unpigmented / ○ 5–8 (rarely up to 10) dorsal blotches / ○ body depth 16.5–20 % SL. Size up to 80 mm SL.

Distribution. Danube drainage: lower and middle Danube upriver to Bratislava, entering only lowermost parts of tributaries; Tisza system in Hungary and Slovakia.

Habitat. Large lowland rivers. Usually in deep water.

Biology. Spawns in Danube and in mouths of some tributaries.

Conservation status. LC.

Further reading. Bănărescu, 1964: 543 (biology, distribution).

Sabanejewia caucasica

Common name. Caucasian golden loach.

Diagnosis. Distinguished from other species of genus by: ● flank marbled, without midlateral rows of dark blotches / ● dark blotches on dorsum often fused / ○ branches of suborbital spine of similar length. Size up to 90 mm SL.

Distribution. Northwestern and southern Caspian basin: from Kuma drainage (Russia) to Babol (Iran).

Habitat. Rivulets and streams 3–10 m wide and less than 1 m deep in foothills and plains, sometimes in channels. Usually on gravel, rarely on sand bottom. Usually along steep banks.

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Sabanejewia bulgarica; Danube delta, Ukraine; ~60 mm SL. A. Naseka

Sabanejewia caucasica; Samur, Russia; ~55 mm SL. A. Naseka

Sabanejewia kubanica; Kuban drainage, Russia; ~50 mm SL.

Biology. Spawns in July – August.
Conservation status. LC.
Further reading. Vasilieva & Poznyak, 1986 (description).

Sabanejewia kubanica

Common name. Kuban golden loach.
Diagnosis. Distinguished from other species of *Sabanejewia* in Europe by: ❍ a midlateral row of dark blotches along flank / ❍ ventral adipose crest on caudal peduncle absent or less developed than dorsal one / ❍ no row of small spots directly below midlateral blotches (if present, most prominent between pelvic and anal bases) / ❍ dorsal origin in front of pelvic origin / ❍ distance between the two dark spots at caudal base much less than their diameter / ❍ interspaces between midlateral blotches with very few or no dark pigments, narrow whitish saddle behind head with dark spots / ❍ mature adults usually about 50–60 mm SL. Size up to 65 mm SL.
Distribution. Russia: Kuban drainage.

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Sabanejewia larvata; Po drainage, Italy; ~75 mm SL.

Sabanejewia romanica; Arges, Danube drainage, Romania; ~80 mm SL.

Habitat. Inhabits a wide range of habitats from small lowland streams to foothill rivers with clear water and gravel bottom.
Biology. No data.
Conservation status. LC.
Further reading. Vasilieva & Vasiliev, 1988 (systematics); Perdices et al., 2003 (genetics).

Sabanejewia larvata

Common name. Italian golden loach.
Diagnosis. Distinguished from other species of genus by: ● blotches on midlateral row numerous (15–27), small and roundish, often fused into an irregular stripe / ○ black spots at caudal base clearly visible, small, distance between them about equal to their diameter / ● dorsal and ventral adipose crests on caudal peduncle similarly developed / ● a dark spot on lower lip / ● at least one row of small spots directly below midlateral blotches. Size up to 80 mm SL.

Distribution. Adriatic basin, in Po and lower Adige drainages (Italy). Introduced in Ombrone, Tevere and Trasimeno drainages (Central Italy).
Habitat. Lowland streams and irrigation canals with still to slow-flowing water and silt bottom with little aquatic vegetation.
Biology. Spawns for the first time at 2 years. Spawns in June.
Conservation status. LC.
Remarks. *Cobitis conspersa* is a synonym.
Further reading. Cavicchioli & Guarnieri, 1969 (identification); Lodi, 1979 (description); Gandolfi et al., 1991: 242 (biology).

Sabanejewia romanica

Common name. Romanian golden loach.
Diagnosis. Distinguished from other species of genus by: ● thin black line along flank / ○ adipose crests on caudal peduncle weakly developed / ○ dark spots at caudal base hardly visible /

Sabanejewia larvata

Sabanejewia romanica

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Sabanejewia vallachica; Ialomita, Danube drainage, Romania; ~65 mm SL. J. Bohlen

O blotches in midlateral row few (8–13) and often horizontally elongated. Size up to 105 mm SL.
Distribution. Romania: Danube basin, Arges, Olt, Jui, Mureş and Tapolitza systems.
Habitat. Sandy streams with clean water and moderate to fast current.
Biology. Spawns in May – July.
Conservation status. NT.
Further reading. Bănărescu, 1964: 531 (biology); Bănărescu et al., 1972 (description).

Sabanejewia vallachica

Common name. Eastern Carpathian golden loach.
Diagnosis. Distinguished from other species of *Sabanejewia* in Europe by: O a midlateral row of dark blotches along flank / O ventral adipose crest on caudal peduncle absent or less developed than dorsal one / O no row of small spots directly below midlateral blotches / O dorsal origin in front of pelvic origin / O distance between the two dark spots at caudal base greater than their diameter / O interspaces between midlateral blotches with very little or no dark pigmentation. Size up to 90 mm SL.
Distribution. Romania: River Ialomita and tributaries of lower River Siret in Danube drainage.
Habitat. Sandy streams with clean water and moderate to fast current. Burrows into sand, rarely in gravel.
Biology. Spawns in spring. Eggs 0.9–1.1 mm in diameter, sticky and indiscriminately scattered over sand, gravel or other substrate. Portion spawner. Eggs hatch in 50–60 h at 22°C. Larvae 3.0–3.4 mm TL start to feed after 6 days. Free larvae lack external gill filaments, but have a transparent bump on forehead.
Conservation status. NT.
Further reading. Nalbant, 1957 (description); Bănărescu, 1964: 531 (biology); Bohlen, 2000 (reproduction).

River Ialomita, Romania; habitat of *Sabanejewia vallachica*.

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Family Nemacheilidae

Stone loaches

A family of loaches from the rivers of Asia, Europe and Ethiopia. The head is usually rounded or depressed, the anterior part of the body is flattened with the pectoral and pelvic fins extended sideways, in many East Asian species so much so that most of the underside acts as a suction pad. Their shape indicates that they live mainly at the bottom of swift-flowing water, where they feed on small invertebrates, algae and detritus. The more specialised Asian species have evolved different modes of locomotion even in strong current by using the specially adapted ventral side and paired fins to hold fast onto stones.

Nemacheiline loaches (about 440 known species in at least 33 genera, mainly in tropical and subtropical Asia) were long classified in the family Cobitidae. Anatomical and phylogenetic studies have shown them to have more affinities with the lineage of the hill-stream loaches (family Balitoridae) of Southeast Asia. Recent molecular data are conflicting; some suggest that nemacheilines are a lineage (subfamily) within Balitoridae, some suggest that they are a distinct lineage (family) apart from the Balitoridae. Whatever their relationships, they are a distinct entity and we recognize them at the family level, which (contrary to the subfamily level) does not imply an hypothesis of relationships with Balitoridae.

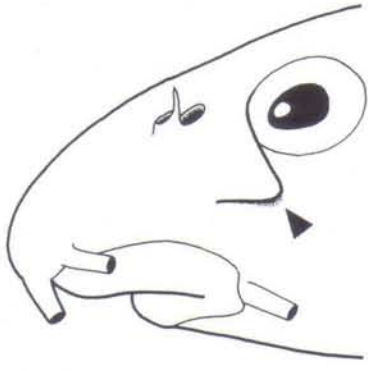

Figure 65 Suborbital flap in some species of Nemacheilidae (after Kottelat, 1990d).

Two genera are known from European waters. *Barbatula* (earlier also called *Orthrias* or *Nemacheilus*; *Nemacheilus* is a genus restricted to Southeast Asia, *Orthrias* is a junior synonym of *Barbatula*) occurs in Europe and northern Asia, and *Oxynoemacheilus* in southeastern Europe and southwestern Asia. *B. barbatula* is reported throughout northern Eurasia, from Spain to Japan, and is usually described as a very variable species. Several species are, however, confused under that name. On the basis of available morphological and molecular data we recognize four valid species in southern Europe. Future studies could show that more species should be recognized.

Males are usually smaller than females. In *Barbatula* species, mature males have upward curled pectorals, longer than those of females, with stiffer and wider rays covered by numerous rows of minute tubercles. In some species, the whole body of males is covered by tiny tubercles in the breeding season. In *Oxynoemacheilus bureschi* (as in many Asian species), males have a suborbital flap (Fig. 65), a modified lachrymal bone; in *O. merga* and *O. pindus*, the flap is absent but there is a small groove in the position of the posterior outline of the lachrymal bone.

Note that, although the correct spelling of the genus name *Nemacheilus* starts with *Ne-*, the correct spelling of the genus name *Oxynoemacheilus* is with *-noe-*.

Further reading. Sawada, 1982 (morphology); Tang et al., 2006 (phylogeny); Slechtová et al., 2007 (phylogeny).

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Key to genera of Nemacheilidae in Europe

1a – Caudal truncate or slightly emarginate; 15–16 branched caudal rays. ..... *Barbatula*

1b – Caudal deeply emarginate or forked; 17 branched caudal rays. ..... *Oxynoemacheilus*

Key to species of *Barbatula* in Europe

1a – Body of adults rugous, covered by small tubercles (Lake Ohrid basin and upper Drin, Macedonia and Albania). ..... *B. sturanyi*

1b – Body of adults smooth. 2

2a – Depth of caudal peduncle 1.1–1.6 (usually 1.3–1.4) times in its length (southern France, northeastern Spain). ..... *B. quignardi*

2b – Depth of caudal peduncle 1.4–2.2 (usually 1.6–2.0) times in its length. 3

4a – Pelvic origin under dorsal origin or under branched dorsal rays 1–2 (most of Europe). ..... *B. barbatula*

4b – Pelvic origin under base of branched dorsal rays 2–4 (Moraca drainage, Montenegro). ..... *B. zetensis*

Barbatula barbatula

Common name. Stone loach.

Diagnosis. Distinguished from other species of *Barbatula* in Europe by: ♦ caudal usually slightly emarginate (truncate in a few populations) / ♦ pelvic origin under dorsal origin or under branched dorsal rays 1–2 / ♦ depth of caudal peduncle 1.4–2.2 (usually 1.6–2.0) times in its length, 1.2–1.8 times in body depth / ♦ often no dark blotches along back between nape and dorsal. Size up to 160 mm SL, usually 60–70 mm SL.

Distribution. Europe north of Caucasus, Pyrénées and Alps, from Loire and Rhône drainages eastward; British Isles (except northern Scotland), southern Sweden and Finland (northward to about 66°N); northeastern Italy; Danube and Vardar drainages.

Habitat. Usually in flowing stretches of streams and medium-sized rivers with gravel to stone bottom, but also in a variety of other habitats, including sandy canals and lake shores. Spawns on gravel, sand or among aquatic vegetation. Larvae and small juveniles prefer sand bottom and slow current, shifting to gravel bottom and fast current when growing.

Biology. Spawns for the first time usually at 1 year in central and southern Europe, 2–3 years in nutrient poor habitats and in northern Europe; most individuals spawn 1–2 seasons. Spawns in April – June at temperatures above 10°C, usually early morning. Open substrate, multiple spawner. Eggs are released in open water, often close to surface, drift and adhere to different substrates; they are often covered by sand or detritus. Individual females may spawn every day for a short period. Larvae benthic. Feeds on relative large benthic in-

Barbatula barbatula; Danube, Germany; ~50 mm SL. A. Hartl

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Barbatula barbatula; Bel Bek, Crimea, Ukraine; ~100 mm SL.

Barbatula barbatula; Vardar drainage, Macedonia; 68 mm SL.

vertebrates (gammarids, chironomids, insect larvae). Tolerant to moderate organic pollution and stream canalisation, very sensitive to pollution by heavy metals.

Conservation status. LC.

Remarks. Often erroneously called *Nemacheilus barbatulus*, *Cobitis barbatula* or *Orthrias barbatula*. Several species are apparently confused under the name *B. barbatula*. Several similar species in Asia, as far as Japan (including *B. toni*, which earlier was considered conspecific).

Further reading. Smyly, 1955 (ecology); Băcescu-Mester, 1967 (morphology); Perrin, 1980 (biology); Bless, 1985 (ecology).

Barbatula quignardi

Common name. Languedoc stone loach.

Diagnosis. Distinguished from other species of *Barbatula* in Europe by: ❍ caudal slightly emarginate / ❍ dorsal origin above or slightly in front of pelvic origin / ❍ depth of caudal peduncle 1.1–1.6 (usually 1.3–1.4) times in its length, 1.2–1.5 times in body depth / ❍ usually 2–4 irregular dark blotches along back between nape and dorsal. Size up to 70 mm SL.

Distribution. France: Lez to Tech drainages (Mediterranean basin) and Adour and Garonne drainages (Atlantic basin); Spain, in Ebro drainage and between Bidasoa and Nervión drainages on eastern Cantabric slope (introduced in Douro drainage).

Habitat. Streams with gravel to stone bottom.

Biology. No data, probably largely similar to *B. barbatula*. Spawns for the first time at 40 mm SL.

Conservation status. LC.

Remarks. The systematic position of the populations from Garonne and Adour drainages has not yet been investigated. Preliminary observations

Barbatula barbatula

Barbatula quignardi

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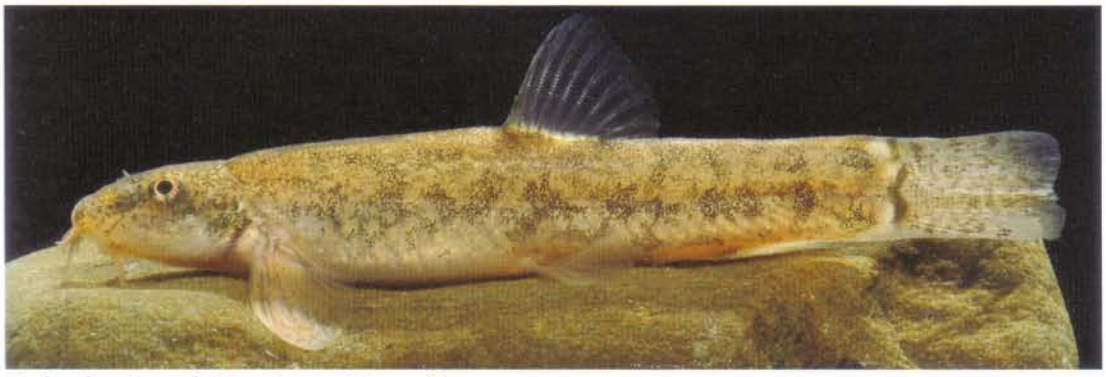
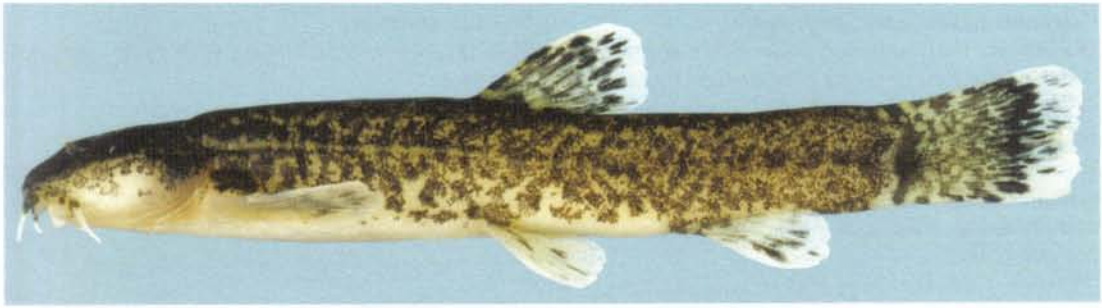


Barbatula quignardi; Lez, France; 68 mm SL.



Barbatula cf. *quignardi*; Dourbie, France; 58 mm SL.

Barbatula sturanyi; Drin, Macedonia; ~70 mm SL. A. Sediva

suggest they are conspecific with or close to *B. quignardi*.

Further reading. Băcescu-Mester, 1967: 359 (morphology).

Barbatula sturanyi

Common name. Ohrid stone loach.

Diagnosis. Distinguished from other species of *Barbatula* in Europe by: ● flank covered by small tubercles in adults (at least in spring), slightly rugous to the touch / ○ caudal truncate / ○ dorsal origin slightly in front of pelvic origin / ○ depth of caudal peduncle 1.6–2.1 times in its depth, 1.7–2.0 times in body depth. Size up to 100 mm SL.

Distribution. Lake Ohrid basin and upper Drin (Macedonia, Albania).

Habitat. Springs along lake shores; streams with stone bottom.

Biology. No data.

Conservation status. LC.

Further reading. Grupče & Dimovski, 1976 (morphometry).

Barbatula sturanyi

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Barbatula zetensis; Moraca, Drin drainage, Montenegro; ~65 mm SL.

Barbatula zetensis

Common name. Zeta stone loach.

Diagnosis. Distinguished from other species of *Barbatula* in Europe by: ♂ pelvic origin under base of branched dorsal rays 2–4 / ♂ 2–4 dark blotches along back between nape and end of dorsal base / ♂ caudal slightly emarginate / ♂ depth of caudal peduncle 1.4–1.8 times in its length, 1.4–1.6 times in body depth. Size up to at least 66 mm SL.

Distribution. Montenegro: Lake Skadar basin, Moraca drainage.

Habitat. Streams and rivers with stone and gravel bottom.

Biology. No data. Lives up to 2 years.

Conservation status. LC.

Further reading. Šorić, 2001: 66 (morphology); Bohlen et al., 2003 (habitat).

Key to species of *Oxynoemacheilus* in Europe

1a – 7½ branched dorsal rays; caudal emarginate; no processus dentiformis (western Caspian basin).
..... *O. merga*

2b – 8½ branched dorsal rays; caudal forked; processus dentiformis present (Fig. 66).
..... 2

2a – Depth of caudal peduncle 1.9–2.3 times in its length; males with suborbital flap (Fig. 65); eye diameter 21–26 % HL (Vardar to Vistonis drainages, Greece, Macedonia and Bulgaria).
..... *O. bureschi*

2b – Depth of caudal peduncle 1.1–1.6 times in its length; males without suborbital flap; eye diameter 16–19 % HL.
..... 3

3a – Depth of caudal peduncle 1.4–1.6 times in its length; lateral line reaching only to anal base (Erzeni to Aoos drainages, Albania and Greece).
..... *O. pindus*

3b – Depth of caudal peduncle 1.1–1.3 times in its length; lateral line reaching caudal base (Lesbos Island, Greece).
..... *O. theophilii*

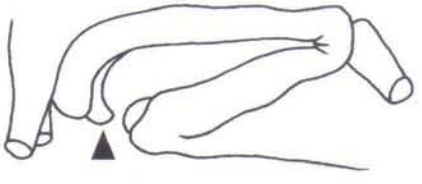

Figure 66 Mouth of Nemacheilidae in lateral view showing the processus dentiformis (arrow) (after Kottelat, 1990d).

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Oxynoemacheilus bureschi; Lake Vistonis drainage, Greece; ~60 mm SL.

Oxynoemacheilus bureschi; Vardar drainage, Macedonia; 59 mm SL.

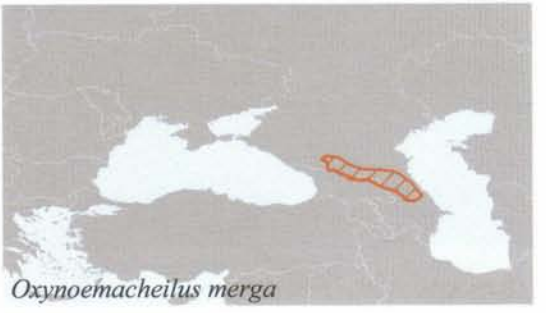
Oxynoemacheilus bureschi

Common name. Struma stone loach.
Diagnosis. Distinguished from other species of *Oxynoemacheilus* in Europe by: ○ caudal forked / ○ depth of caudal peduncle 1.9–2.3 times in its length / ○ eye diameter 21–26 % HL / ● adult males with suborbital flap (Fig. 65) / ○ lateral line reaching caudal base / ○ 8½ branched dorsal rays / ○ processus dentiformis present. Size up to 65 mm SL.
Distribution. Vardar to Vistonis drainages (Macedonia, Bulgaria, Greece).
Habitat. Flowing water with gravel to stone bottom, usually in riffles and rapids.
Biology. Spawns in June.
Conservation status. LC.
Further reading. Bănărescu et al., 1978: 261 (diagnosis); Šorić, 2000 (as *Orthrias brandti macedonicus*; description); Kottelat & Freyhof, 2007b (systematics).

Oxynoemacheilus merga

Common name. Caucasus stone loach.
Diagnosis. Distinguished from other species of *Oxynoemacheilus* in Europe by: ● caudal emarginate / ○ depth of caudal peduncle 2.1–2.4 times in its length, 2.0–2.5 times in body depth / ● no processus dentiformis / ● 7½ branched dorsal rays. Size up to 100 mm SL.
Distribution. Western Caspian basin in Europe: Kuma, Terek, Sulak, Shura-ozen and Samur drainages.
Habitat. Upper montane reaches of rivers.
Biology. No data.

Oxynoemacheilus bureschi



Oxynoemacheilus merga

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Oxynoemacheilus merga; Rubas drainage, Russia; ~60 mm SL. A. Naseka

Oxynoemacheilus pindus; Devoli drainage, Albania; ~70 mm SL. A. Sediva

Conservation status. LC. Apparently rare, but possibly overlooked.
Further reading. Berg, 1949: 873 (description).

Oxynoemacheilus pindus

Common name. Pindus stone loach.
Diagnosis. Distinguished from other species of *Oxynoemacheilus* in Europe by: ○ caudal forked / ○ depth of caudal peduncle 1.4–1.6 times in its length / ○ eye diameter 16–18 % HL / ○ males without suborbital flap / ● lateral line reaching only to anal base / ○ 8½ branched dorsal rays. Size up to 54 mm SL.
Distribution. Albania, Greece: Aoos, Semani, Shkumbini and Erzeni drainages.
Habitat. Creeks and streams with stone bottom, in riffles.
Biology. No data.
Conservation status. VU B1ab(iii) + 2ab(iii).
Further reading. Economidis, 2005 (description).

Oxynoemacheilus theophilii

Common name. Lesbos stone loach.
Diagnosis. Distinguished from other species of *Oxynoemacheilus* in Europe by: ○ caudal forked / ○ depth of caudal peduncle 1.1–1.3 times in its length / ○ eye diameter 17–19 % HL / ○ males without suborbital flap / ○ lateral line reaching caudal base / ○ 8½ branched dorsal rays. Size up to 54 mm SL.
Distribution. Greece: Lesbos Island, stream Evergetoulas. Turkey: from Bakir to Great Menderes drainages.
Habitat. Upper part of stream, with current and clear, cold water.
Biology. No data.

Oxynoemacheilus pindus

Oxynoemacheilus theophilii

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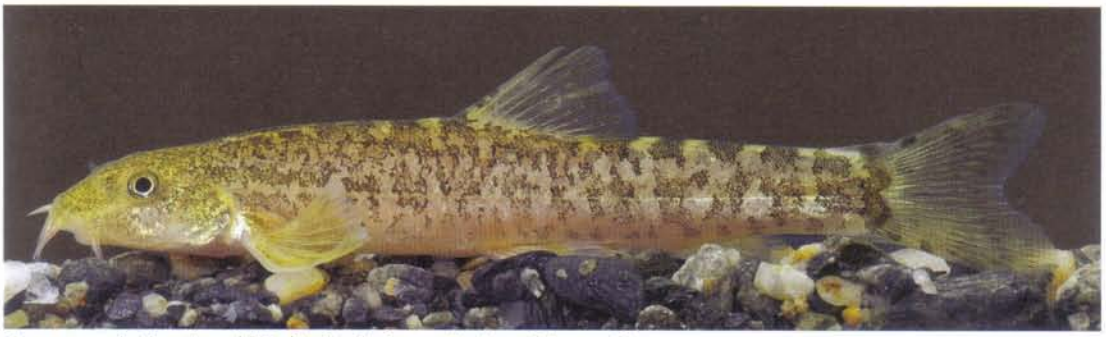
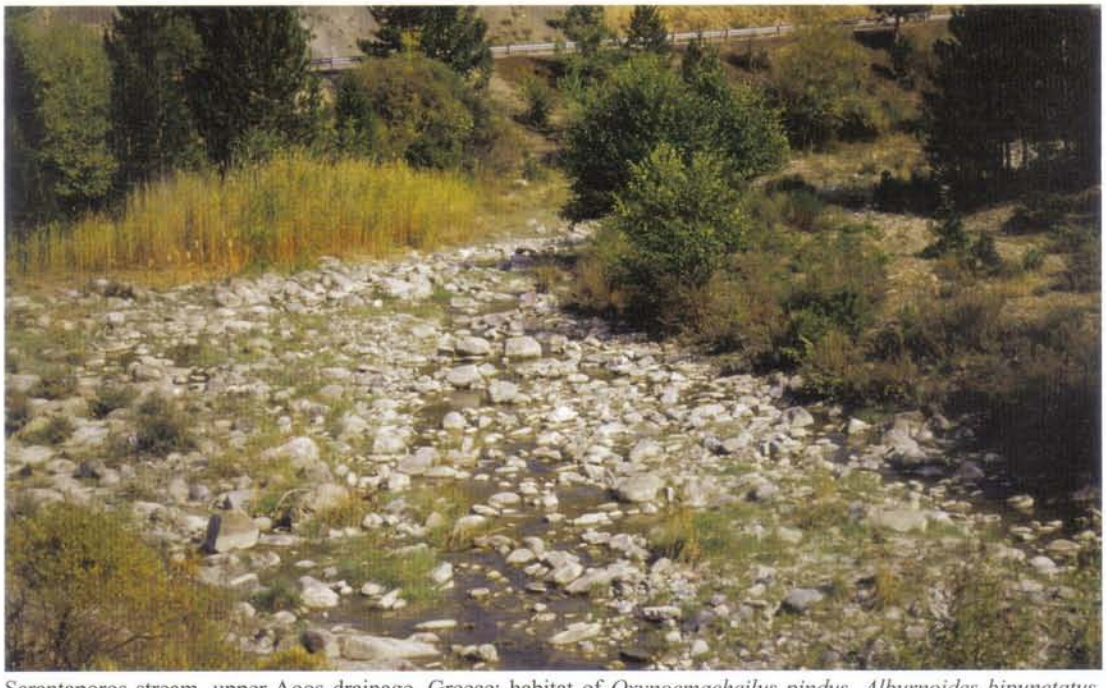


Oxynoemacheilus theophilii; Gediz drainage, Turkey; 70 mm SL.

Oxynoemacheilus theophilii; Lesbos Island, Greece; 63 mm SL.

Conservation status. LC; due to water abstraction. In Europe, known from a single spring on Lesbos Island.

Further reading. Stoumboudi et al., 2006: 140 (description); Erk'akan et al., 2007: 71 (as *Barbatula bergamensis*).



Sarantaporos stream, upper Aoos drainage, Greece; habitat of *Oxynoemacheilus pindus*, *Alburnoides bipunctatus*, *Barbus rebeli*, *Chondrostoma vardarensis*, *Pachychilon pictum* and *Squalius* sp. Aoos.

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Family Ictaluridae

North American catfishes

Ictaluridae are endemic to North and Central America south to Guatemala. The family includes about 50 species in 6 genera, 3 of which (*Satan*, *Trogloglanis*, *Prietella*) are white and eyeless inhabitants of subterranean habitats in Texas and Mexico. Ictalurids are easily distinguished from European catfishes by the presence of an adipose fin (vs. absence). The first *Ameiurus* were imported to Germany in 1885. At least three species have been introduced in European waters but more species of *Ameiurus* may be involved, confused with these species. *Ameiurus natalis* is occasionally mentioned as being introduced in Europe, but we found no reliable evidence of this. This species is distinguished from *A. melas* and *A. nebulosus* by whitish or yellowish mental barbels (vs. brown or black) and 23–26½ anal rays (vs. 19–23½). The identification of *Ameiurus* species is difficult. The colour (brown = *A. nebulosus*, black = *A. melas*) and anterior serrae on pectoral spine (serrated = *A. nebulosus*, not serrated = *A. melas*) have often been used as identification criteria but these are not reliable characters and have led to great confusion as to the identity of the species in Europe. As a result, the actual distribution of the various species is almost impossible to outline without re-examining material from each population.

Further reading. Taylor, 1969 (systematics); Lundberg, 1982 (phylogeny), 1992 (phylogeny); Stoeckel & Burr, 1999 (reproduction); Hardman & Page, 2003 (phylogeny).

Key to species of Ictaluridae in European waters

1a – Caudal deeply forked; juveniles and small adults usually with dark spots on body. ..... *Ictalurus punctatus*

1b – Caudal emarginate; body without dark spots. 2

2a – No serrae on pectoral spine in individuals about 30–50 mm SL, or only a few weak notches (Fig. 67a), small and generally inconspicuous in adults; usually 15–19 gill rakers in individuals larger than 50 mm SL; a pale bar at base of caudal rays; membranes of caudal and anal black with contrasting pale rays. ..... *Ameiurus melas*

2b – 2–3 weak anterior serrae and 2–4 small and sharp posterior serrae on pectoral spine in individuals about 30–50 mm SL (Fig. 67b), large in adults; usually 11–14 gill rakers in individuals larger than 50 mm SL; no pale bar at base of caudal rays; membranes of caudal and anal not contrasting sharply with rays. ..... *Ameiurus nebulosus*

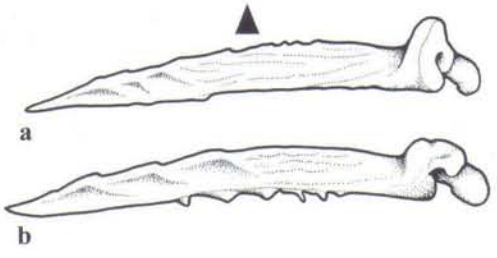

Figure 67 Pectoral spine of juvenile *Ameiurus* species. **a,** *A. melas*; **b,** *A. nebulosus*. Arrow points towards head (after Jenkins & Burkhead, 1994).

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Ameiurus melas; Adour, France; 157 mm SL.

Ameiurus melas; Rhine drainage, Germany; ~200 mm SL.

Ameiurus melas

Common name. Black bullhead.

Diagnosis. Distinguished from *A. nebulosus* by: O at about 30–50 mm SL, no serrae or only a few weak notches on pectoral spine (Fig. 67a) / O serrae on pectoral spine small and generally inconspicuous in adults / O usually 15–19 gill rakers in individuals larger than 50 mm SL / O adults with belly usually whitish / O membranes of caudal and anal black with contrasting pale rays / O a pale bar at base of caudal rays. Size up to 495 mm SL.

Distribution. Native to eastern half of North America, from southern Canada to northern Mexico. Widely introduced to other parts of North America, south America, Asia and Europe. In Europe self-sustaining populations recorded from Ebro and Tagus drainages (Iberian Peninsula), most drainages of France, locally in Italy, the Netherlands and Germany. Could have a wider distribution. Often misidentified as *A. nebulosus*.

Habitat. Usually in backwaters and pools in large lowland streams and rivers, in ponds, nutrient-rich lakes, and reservoirs.

Biology. Lives up to 9 years. Spawns for the first time at 3 years. Spawns in May – July, at about 18–30°C. Individual females usually spawn only once per year. The female excavates a nest in sand bottom, in shallow water. One or both parents take care of the eggs and guard the nest and the early juveniles. Eggs hatch in 5 days. Larvae and juveniles form dense swarms in open water, and are often seen at the surface during first summer. Omnivorous; feeds mainly on algae, plant material, invertebrates and fish. Nocturnal.

Conservation status. Alien.

Further reading. Scott & Crossman, 1974: 633 (biology); Jenkins & Burkhead, 1993: 551 (biology); Bailey et al., 2004: 41 (identification); Boschung & Mayden, 2004: 329 (identification).

Ameiurus nebulosus

Common name. Brown bullhead.

Diagnosis. Distinguished from *A. melas* by: O at about 30–50 mm SL, 2–3 weak anterior serrae and 2–4 small and sharp posterior serrae on pectoral spine (Fig. 67b) / O large serrae on pectoral spine in adults / O usually 11–14 gill rakers in individuals larger than 50 mm SL / O adults with belly usually whitish / O dark pigments on anal usually densest on membrane near margin, or more or less mottled, rays and membranes about equally pigmented / O no pale bar at base of caudal rays. Size up to 430 mm SL.

Distribution. Native to North America, from

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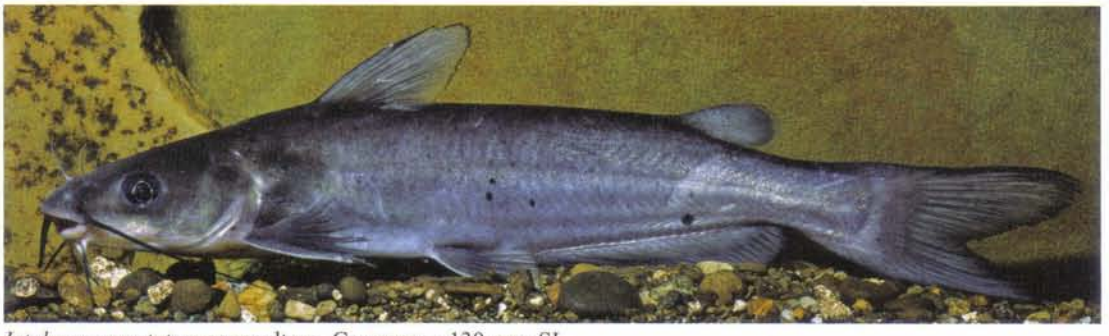
Ameiurus nebulosus; Elbe, Germany; ~250 mm SL (dorsal spine missing).



Ictalurus punctatus; aquaculture, Germany; ~130 mm SL.

southern Canada to Florida and Mississippi drainage. Widely introduced elsewhere in North America, south America, Asia and Europe. In Europe, self-sustaining populations recorded from Germany and Italy, eastward to Kuban and Volga drainages and north to 64°N in central Finland. Could have a wider distribution. Often misidentified as *A. melas*.

Habitat. Backwaters and pools of large lowland streams and rivers, ponds, nutrient-rich lakes, and reservoirs.

Biology. Lives up to 9 years. Spawns for the first time at 2–3 years. Spawns in April – May, later in the north, when temperature reaches 15°C. May spawn more than once each year. Nesting occurs in shallow water, usually under logs or other cover. One or both parents take care of the eggs (fanning, cleaning with the mouth) and guard the nest. Eggs hatch in 6–9 days. Larvae and juveniles form dense swarms in open water, and are often seen at the surface during first summer. Omnivorous; feeds on algae, plant material, invertebrates and fish. Nocturnal.

Conservation status. Alien.

Further reading. Scott & Crossman, 1974: 641 (biology); Jenkins & Burkhead, 1993: 547 (biology); Bailey et al., 2004: 41 (identification); Boschung & Mayden, 2004: 331 (identification).

Ictalurus punctatus

Common name. Channel catfish.

Diagnosis. Distinguished from other catfishes in Europe by: ● caudal deeply forked / ○ adipose present / ○ juveniles and small adults usually with dark spots. Size up to 1000 mm SL, usually less than 570 mm SL.

Distribution. Native to North America, in Hudson Bay, Great Lakes-St. Lawrence and Mississippi drainages, and rivers inbetween. Widely introduced elsewhere in North America. Introduced for aquaculture in Europe. Self-sustaining populations recorded in lower Ebro (Spain), River Oglio and Pavia Province (northern Italy), and lower Kuban and Don drainages. Could occur also in other areas.

Habitat. Warm lowland rivers and large streams, ponds, lakes and reservoirs. Usually associated with low-current riverine habitats. Also in upper estuarine habitats with salinity up to 15 ‰.

Biology. Lives up to 24 years. Spawns for the first time at 4–6 years. Spawning starts in May, at about 20–30°C. Nests are constructed in sheltered areas by male only or by both sexes. Males take care of eggs and guard the nest. Females spawn only once a year. Eggs hatch in 5–10 days. Omnivorous; feeds on algae, plant material, invertebrates and fish. Usually nocturnal.

Conservation status. Alien.

Further reading. Scott & Crossman, 1974: 647 (biology); Jenkins & Burkhead, 1993: 535 (biology).

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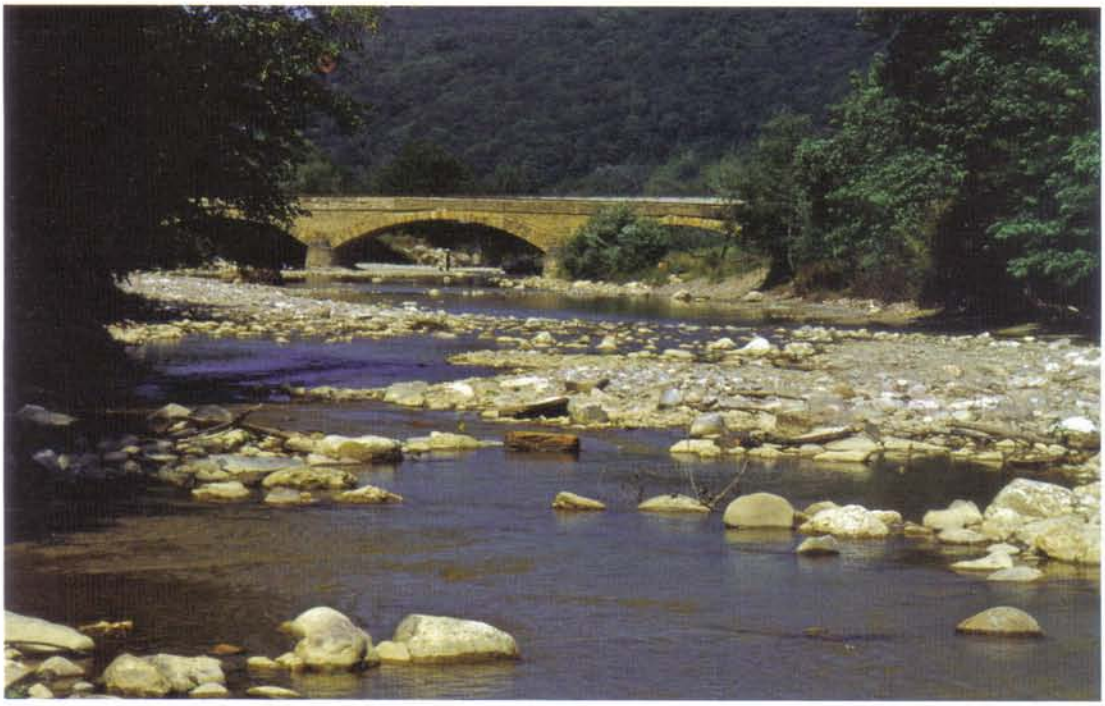

Tributary of River Kuban, Russia; habitat of *Barbatula barbatula*, *Sabanejewia kubanica*, *Barbus kubanicus* and *Squalius cephalus* .

Upper Arges, Romania; habitat of *Cottus transsilvaniae*, *Barbus petenyi*, *Phoxinus phoxinus* and *Sabanejewia romanica*.

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Family Siluridae

Catfishes

A family of freshwater catfishes found in Europe and Asia. They are characterised by the lack of the adipose fin, the lack of the dorsal spine or, sometimes, the entire dorsal fin, and by a very long anal fin. Some are small (adult at about 50 mm SL, as the glass catfish *Kryptopterus minor* from Southeast Asia, frequently seen in aquariums) but others are large, and one of the European species grows to over 3 m in length. They inhabit the lower strata of rivers and lakes where they prey on smaller fish.

Further reading. Bornbusch, 1991, 1995 (systematics).

Silurus aristotelis

Common name. Acheloos catfish.

Diagnosis. Distinguished from *S. glanis* by: ● one pair of mental barbels / ● 66–75½ total anal rays. Size up to about 400 mm SL.

Distribution. Greece: Acheloos drainage. Introduced in Lakes Pamvotis and Volvi.

Habitat. Lowland rivers, nutrient-rich lakes.

Biology. Lives up to 10 years. Spawns for the first time at 2–3 years. Spawns repeatedly in April – July. At the spawning sites, males defend small territories and build nests of plant material, dig shallow depressions or clean spawning substrate, at 2–3 m depth. Nests are defended by males until larvae emerge. Spawns in pairs. During spawning act, the male embraces the female. Eggs hatch in 5 days. Feeds at night, mainly on fish, additionally on crustaceans, gastropods, insects, amphibians and aquatic snakes.

Conservation status. DD.

Remarks. Spawning behaviour was already described by Aristotle (384–322 BC), possibly the first written account of fish biology.

Further reading. Agassiz, 1856 (Aristotle's account); Iliadou & Ondrias, 1986 (biology); Kobayakawa, 1989: 158 (description); Economou et al., 1994a: 28 (larvae).

Silurus glanis

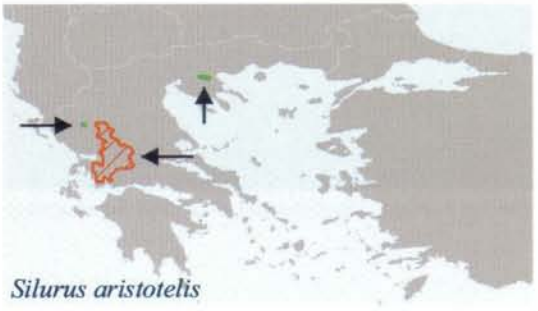
Common name. European catfish.

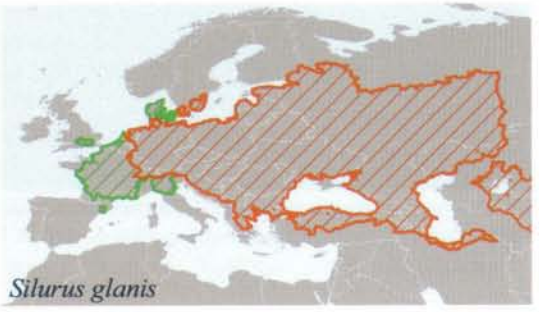
Diagnosis. Distinguished from all other European freshwater fishes by: ● two pairs of mental barbels / ● 83–91½ total anal rays / ○ scaleless body / ○ large, depressed head / ○ 2–4½ dorsal rays / ○ caudal rounded or truncate / ○ no adipose / ○ anal rays almost touching caudal. Size reportedly up to 5000 mm SL and 300 kg, usually up to about 2000 mm SL and 80 kg.

Distribution. North, Baltic, Black, Caspian and Aral Sea basins, as far north as southern Sweden and Finland; Aegean Sea basin, in Maritza and from Stuma to Sperchios drainages; Turkey. Absent from rest of Mediterranean basin. Introduced in Rhône drainage in 1857 and in British Isles during second half of 19th century. Now widely introduced and translocated throughout Europe and Lake Balkhash basin (Kazakhstan).

Habitat. Large and medium size lowland rivers, backwaters and well vegetated lakes. Spawns in shallow, warm and well vegetated riverine habitats without current.

Biology. Lives up to 80 year in the wild. Spawns


Silurus aristotelis


Silurus glanis

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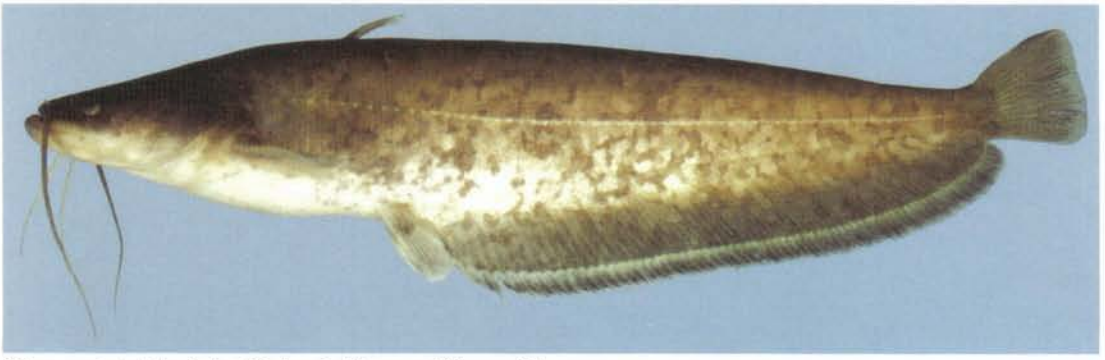
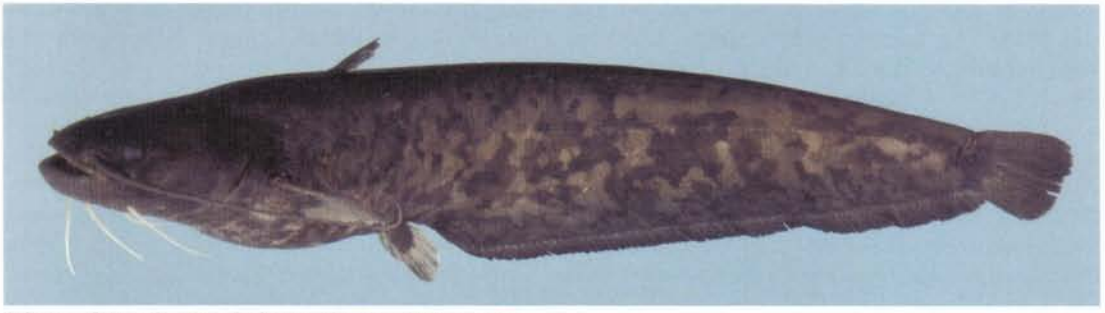


Silurus aristotelis; Lake Trichonis, Greece; 193 mm SL.



Silurus glanis; Struma drainage, Greece; 200 mm SL.

Silurus glanis; Danube drainage, Germany; ~750 mm SL. A. Hartl

for the first time at 2–3 years and 1–2 kg. Spawns in April – June, in northern areas until August, when temperature reaches about 20°C. In spawning sites, males defend small territories and build nests of plant material, dig shallow depressions or clean spawning substrate such as willow (*Salix*) roots. Nests are defended by males until larvae emerge. Spawns in pairs. During spawning act, the male embraces the female. Eggs hatch in 2–3 days and larvae remain in nest until yolk sack is absorbed (2–4 days). A nocturnal predator, feeding near bottom and in water column. Very sensitive to extra-aquatic sounds. Head sensory canal system allows to track the wakes [a trail of hydrodynamic and chemical signatures left by a swimming fish] of prey up to 10 seconds old over distances up to 55 times the length of the prey. Larvae and juveniles benthic and negatively phototactic, feeding on a wide variety of invertebrates and fish. Adults feed on fish and other aquatic vertebrates.

Conservation status. LC. Locally threatened due to river regulation destroying shallow spawning sites.

Further reading. Mohr, 1957 (biology); Kobayakawa, 1989: 164 (description); Pohlmann et al., 2004 (wakes).

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Family Esocidae

Pikes

Small family of highly distinctive, predatory fishes with large, duckbill-like snout, and dorsal and anal fins located far back on body. One genus (*Esox*) with 5 species, 3 of them endemic to North America, *E. lucius* in North America and Eurasia and *E. reichertii* endemic to Amur basin (Russia, Mongolia, China). Because of its commercial value, *E. lucius* is widely stocked throughout Europe. In Spain, stocked *E. lucius* are responsible for the local extirpation of almost all fish species in some habitats, where they maintain high population densities and feed predominantly on crayfish (also introduced).

Further reading. Crossman, 1978 (systematics).

Esox lucius

Common name. Pike.

Diagnosis. Distinguished from all other European freshwater fishes by: ❍ long snout / ❍ large mouth / ❍ dorsal origin slightly in front of anal origin / ❍ 105–148 total lateral line scales. Size up to 1300 mm SL.

Distribution. Caspian, Black, Baltic, White, Barents, Arctic, North and Aral Seas and Atlantic basins, southwest to Adour drainage; Mediterranean basin, in Rhône drainage and northern Italy. Widely distributed in North America, central Asia and Siberia eastward to Anadyr drainage (Bering Sea basin). Historically absent from Iberian Peninsula, Mediterranean France, central Italy, southern and western Greece, eastern Adriatic basin, Iceland, western Norway and northern Scotland. Now widely introduced and translocated throughout Europe.

Esox lucius

Habitat. In a wide variety of habitats with aquatic or periodically flooded vegetation. Often semi-anadromous in part of northern Baltic basin with lower salinity.

Biology. Males reproduce for the first time at 170–350 mm SL, females at 250–400 mm SL, at 1–6 years. Reproduction closely related to the presence of submerged vegetation. Spawns in late winter or early spring, between February in the south and June in the north, when temperature rises above 5°C. Several males court a single female. Eggs are deposited in flooded areas and on submerged vegetation over a period of 2–5 days. Juvenile survival is negatively related to biomass of older individuals and positively related to the area of the patches covered by submerged vegetation. Feeds on various small vertebrates, predominantly fish, and large invertebrates as decapod crustaceans. Cannibalism is common. In arctic lakes, it is sometimes the only fish species in a given water body; in such cases, juveniles feed on invertebrates and terrestrial vertebrates; large individuals are predominantly cannibals. Other fish avoid places with faeces of pike because they contain alarm pheromones; therefore pikes deposit their faeces at specific locations, distant from their foraging area.

Conservation status. LC. Locally negatively affected by habitat alterations.

Further reading. Craig, 1996 (biology); Casselman et al., 1986 (morphology).

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Esox lucius; Danube drainage, Germany; ~350 mm SL. A. Hartl

Esox lucius; Danube, Slovakia; 450 mm SL.

Esox lucius; Danube drainage, Germany; cannibali venile, ~90 mm SL. A. Hartl

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Family Umbridae

Mudminnows

A small family with two genera (*Umbra*, *Novumbra*), with one species in Europe (*U. krameri*) and three in North America (*U. limi*, *U. pygmaea*, *N. hubbsi*). *U. pygmaea* is locally introduced in western and Central Europe. The related genus *Dallia* from Alaska and Siberia is now considered to constitute a distinct family (Dalliidae). Umbridae are distinctive, small fishes with short snout, toothed jaws, no adipose fin, pelvic fin at about middle of body, dorsal fin located behind pelvic-fin origin, fins without spines and rounded caudal fin.

Further reading. Wilson & Veilleux, 1982 (systematics).

Umbra krameri

Common name. European mudminnow.

Diagnosis. Distinguished from *U. pygmaea* by: ○ 33–35 total scales in midlateral series / ● body and head irregularly strewn with small dark spots / ● no dark blotch at caudal base. Size up to 100 mm SL.

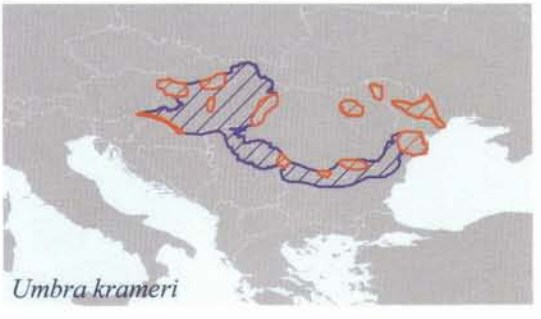
Distribution. Scattered distribution in Danube drainage from Vienna to delta; lower reaches of Dniestr drainage.

Habitat. Very densely vegetated water bodies, usually in small ditches, oxbows, backwaters and shallow lakes.

Biology. Lives up to 5 years. Spawns for the first time at 1 year. Spawns in March – April, when temperatures reach 12–16°C. Eggs are laid in a nest of plant material or in a shallow depression in the bottom. Single portion spawner. Females protect the nest until the larvae leave it. Able to breathe atmospheric air and may therefore colonise habitats with very low oxygen concentrations. Feeds on a variety of small animals.

Conservation status. VU A2c.

Further reading. Mikschi & Wanzenböck, 1995 (biology, conservation); Wanzenböck, 2004 (conservation).



Umbra krameri

Umbra pygmaea

Common name. Eastern mudminnow.

Diagnosis. Distinguished from *U. krameri* by: ○ 30–34 total scales in midlateral series / ● prominent ovoid, dark blotch at caudal base / ● body and head without dark spots. Size up to 120 mm SL.

Distribution. Native to Atlantic coast of North America from southern New York to northern Florida. Introduced (but very localised) to central and western Europe (France, Belgium, Netherlands, Germany, Poland).

Habitat. A wide variety of lowland habitats as small, still and well vegetated water bodies, backwaters, ponds and irrigation channels. In Europe usually in small isolated ponds and peat bogs.

Biology. Spawns for the first time at 2 years. Spawns in March – May, at 10–15°C. Eggs laid in a nest of plant material, in a shallow depression in bottom or between rocks. After spawning, both sexes frequent and may guard the nest until the larvae leave it. Able to breathe atmospheric air and therefore to colonise habitats with very low oxygen concentrations. Feeds on a variety of small invertebrates.

Conservation status. Alien.

Further reading. Jenkins & Burkhead, 1993: 247 (biology); Guidou & Keith, 2002 (introduction); Schmidt & Daniels, 2006 (description, taxonomy).

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Umbra krameri; Kescemet, Hungary; ~70 mm SL. A. Hartl

Umbra krameri; Tisza system, Hungary; ~80 mm SL. A. Hartl

Umbra pygmaea; aquarium trade; ~90 mm SL.

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Family Osmeridae

Smelts

A family of small, slender, silvery fishes, with an adipose dorsal fin, a large mouth with numerous small teeth, and an incomplete lateral line. Most species have a strong cucumber smell when taken out of the water. The family inhabits all northern seas in Europe, Asia and America. Most species are anadromous and form large schools. Seven genera and about 13 species. The taxonomic status of several landlocked populations need to be re-examined. The Japanese ayu (*Plecoglossus altivelis*), formerly placed in the family Plecoglossidae, is now placed in Osmeridae.

Further reading. McAllister, 1963 (systematics); Gruchy & McAllister, 1972 (bibliography); Wilson & Williams, 1991 (relationships); Taylor & Dodson, 1994 (genetics).

Key to species of Osmeridae in European freshwaters

1a – Jaws short, maxilla reaching at most to middle of eye (from Arctic Ocean coast to Canada). ..... *Hypomesus olidus*

1b – Jaws long, maxilla reaching to or beyond posterior margin of eye. 2

2a – Dorsal origin slightly in front of pelvic origin; 13–28 pored scales in lateral line; 65–72 total scales in midlateral row (from Arctic Ocean coast to Canada). ..... *Osmerus dentex*

2b – Dorsal origin distinctly behind pelvic origin; 2–14 pored scales in lateral line; 58–69 total scales in midlateral row (Atlantic and northern coasts of Europe). ..... *Osmerus eperlanus*

Hypomesus olidus

Common name. Pond smelt.

Diagnosis. Distinguished from other species of Osmeridae in Europe by: ● short jaws, maxilla reaching at most middle of eye / ● teeth small / ● posterior margin of dorsal convex / ○ 53–60 total scales in midlateral row / ○ 10–16 pored scales in lateral line. Size up to 160 mm SL.

Distribution. Rivers, estuaries and coastal waters of European and Siberian shores of Arctic Ocean, from Kara drainage to Chukotka (eastern Siberia) and to Korea and Hokkaido (Japan); in America, from Copper to Kobuk (Alaska) and Mackenzie (Canada) drainages.

Hypomesus olidus

Habitat. Brackish water of estuaries, lagoons, coastal waters of open sea; freshwater of lowland and piedmont rivers and lakes. Anadromous populations pelagic at sea, commonly at 4–5 m depth and spawning in rivers. Landlocked populations may spawn in lakes or migrate to their tributaries. Spawns along shallow river shores and in backwaters with little or no current, often in lakes, on sand or gravel bottom.

Biology. Anadromous and landlocked populations. Does not migrate long distances. Enters deltas and lower reaches of rivers in September – December to overwinter, then returns to sea and rivers for spawning. Spawns for the first time at 2 years. Spawns in April – July. Eggs are about 0.75 mm in diameter. Eggs hatch in 11–16 days. Juveniles

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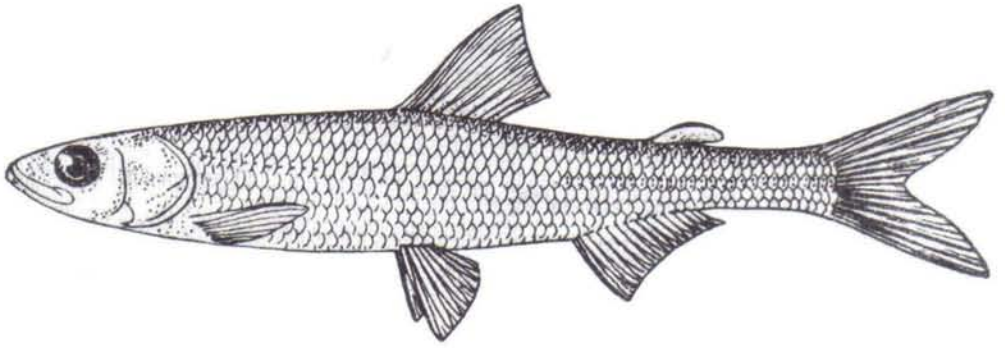
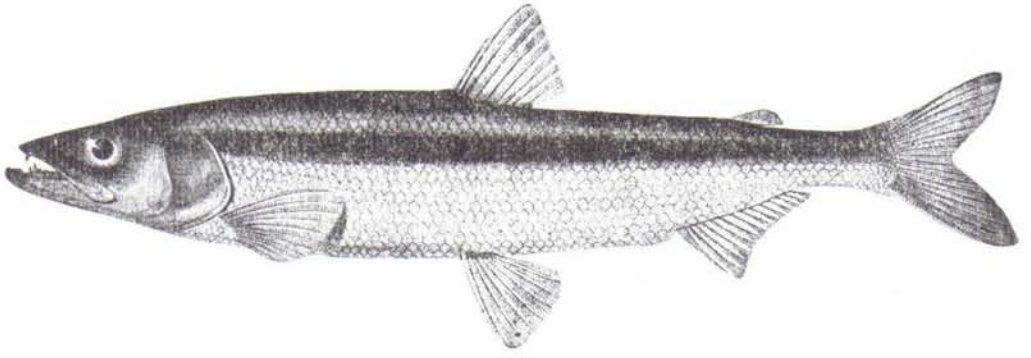


Hypomesus olidus; Russia; 58 mm SL. (from Nikolski, 1956)



Osmerus dentex; Vladivostok, Russia; 248 mm SL. (from Berg, 1932)

remain close to spawning sites for a year or longer, then migrate to sea or estuaries. Feeds on zooplankton, mostly crustaceans.

Conservation status. LC.

Further reading. McAllister, 1963: 31 (taxonomy); Scott & Crossman, 1974: 332 (biology); Klyukanov, 1970 (systematics); Saruwatari et al., 1997: 73 (systematics); Shedko, 2001 (diagnosis).

Osmerus dentex

Common name. Pacific rainbow smelt.

Diagnosis. Distinguished from other species of Osmeridae in Europe by: O long jaws, maxilla reaching to or beyond posterior margin of eye / O large teeth on tongue and vomer / O 65–72 total scales in midlateral row / O 13–28 pored scales in lateral line / O dorsal origin slightly in front of pelvic origin. Size up to 340 mm SL.

Distribution. Estuaries and coastal waters of European and Siberian shores of Arctic Ocean, from White Sea to Chukotka (eastern Siberia), Korea and Hokkaido (Japan); America from Vancouver Island to Coronation Bay.

Habitat. Brackish water of estuaries, lagoons, coastal shallows and bays; fresh water in lowland and piedmont rivers. At sea, pelagic, at 4–8 m depth. Spawns in rapids, in clear water, over stone-gravel bottom and depth 0.2–0.5 m.

Biology. Anadromous. Enters rivers only for spawning, first at 3–4 years. Lives up to 11 years. Spawning migration starts in April – May under ice. Distance of migration depends on availability of spawning sites, from tens to thousands of kilometres. Usually spawns in May – June and returns to sea soon after. Spawns at 7–14°C. Eggs are yellow, 0.8–1.0 mm in diameter, and adhere to pebbles and stones. Eggs hatch in 18–25 days at 5–18°C. Larvae and young juveniles feed on zooplankton, larger juveniles mostly on gammarids and mysids. By August, juveniles migrate to sea. Becomes piscivorous when reaching sexual maturity. Feeds mostly on smaller, schooling fishes, usually juveniles of cod (*Gadus morhua*), Salmo-

Osmerus dentex

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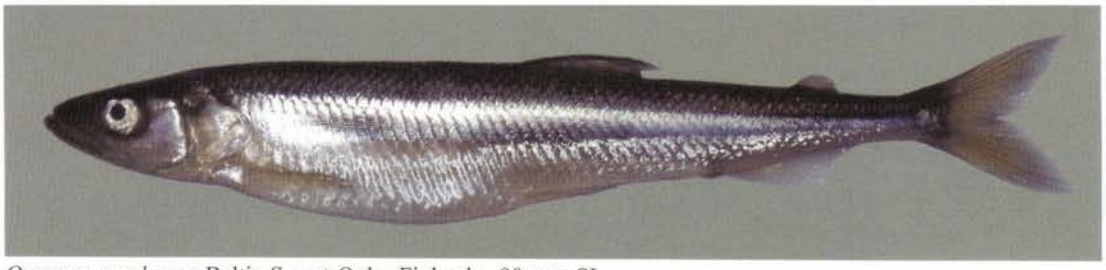
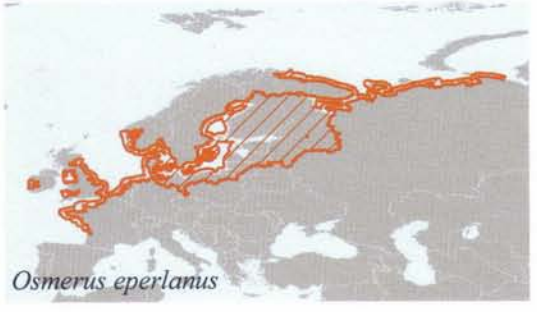


Osmerus eperlanus; Baltic Sea at Oulu, Finland; ~90 mm SL.

nidae, Clupeidae and Coregonidae.
Conservation status. LC.
Remarks. Earlier treated as subspecies or synonym of *O. mordax* but morphological and genetic data indicate they are distinct species, *O. mordax* being restricted to the East coast of Canada and the North American Great Lakes.
Further reading. McAllister, 1963: 15 (taxonomy); Klyukanov, 1975 (morphology, systematics); Shedko, 2001 (systematics).

Osmerus eperlanus

Common name. Smelt.
Diagnosis. Distinguished from other species of Osmeridae in Europe by: ○ long jaws, maxilla reaching to or beyond posterior margin of eye / ○ large teeth on tongue and vomer / ○ 58–69 total scales in midlateral row / ○ 2–14 pored scales in lateral line / ● dorsal origin distinctly behind pelvic origin. Size up to 270 mm SL, usually up to about 80 mm SL in landlocked populations.
Distribution. Coastal waters of White, Barents, Baltic and North Seas, Great Britain, western Ireland, Atlantic Ocean southward to Garonne estuary. Landlocked populations in lakes of coastal areas of North, Baltic, White and Barents Seas. North to about 68°N in Scandinavia.
Habitat. Pelagic inhabitant of marine waters, estuaries and large lakes. Spawns in tributaries of lakes or along shallow shores of lakes and rivers, on sand, gravel, stones and plant material, preferably in fast-flowing water.
Biology. Anadromous and landlocked populations. Anadromous individuals spawn at 2 years, landlocked ones often at 1 year. Anadromous individuals live up to 7 years. Landlocked populations and large parts of anadromous populations usually reproduce only once in their life. Spawning migration starts in September – October, when mature fishes aggregate in estuaries to overwinter. Upriver migration starts in March – April when temperatures rise above 3–6°C and during rainy and stormy weather. Spawning migration reaches only the lower part of rivers. Older individuals and males migrate earlier than younger ones and females. Spawns in March – April at 4–12°C. Eggs are sticky and attached to substrate. Large numbers of eggs are washed from substrate and drift, with attached sand above river bottom. Eggs hatch in 20–35 days; larvae drift to estuaries. After spawning, adults migrate to sea, remain in coastal waters close to estuaries. Juveniles prefer fresh or brackish water until they mature. May reach high densities and experience large fluctuations in abundance. Feeds on zooplankton and small fishes, which often are juveniles of its own species.
Conservation status. LC. Locally threatened by pollution and barriers to migration.
Remarks. Available data do not exclude the possibility of two species are possibly confused under the name *O. eperlanus*: *O. eperlanus*, usually with 33–38 gill rakers, primarily lacustrine, from coastal areas of White, Barents and Baltic Seas, and *O. schonfoldi*, usually with 27–32 gill rakers, primarily anadromous, from Atlantic, southern Baltic and North Sea. The two species would be sympatric in parts of Poland, Denmark and southern Baltic.
Further reading. Lillelund, 1961 (biology); McAllister, 1963: 20 (systematics); McAllister, in Whitehead et al., 1984: 401 (description); Shedko, 2001 (systematics).



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Family Coregonidae

Whitefishes, vendaces, ciscoes

A family of small to large fishes, with slender and compressed, silvery body, covered by numerous small scales (60–110), an adipose dorsal fin, and very small or absent teeth. The family includes marine, anadromous and pure freshwater species in northern Europe, Asia and North America. Most species are pelagic, form schools and feed on small crustaceans. In autumn both sexes of most species develop nuptial tubercles on each lateral scale.

Most species have a high commercial value and are intensively fished, some are cultivated, fry of many populations and species are produced artificially and stocked outside their native range, resulting in hybrid stocks, and other manipulations. The genetic integrity of several wild populations and species is threatened; some species are extinct following the formation of hybrid swarms and habitat modification (water quality as well as topography of spawning sites). The non-recognition that many 'populations' are in fact distinct species is (or will be) the main cause for the loss of numerous species. The trend is changing in some areas (e.g. subalpine lakes) where fry of the different species are produced separately.

Further reading. Kottelat, 1997 (systematics, nomenclature).

Key to genera of Coregonidae in Europe

1a – Mouth large, articulation of lower jaw with cranium behind posterior margin of eye; lower jaw with conspicuous symphysial knob (Fig. 68).
..... *Stenodus*

1b – Mouth small, articulation of lower jaw with cranium before or below posterior margin of eye; lower jaw without symphysial knob.
..... 2

2a – Mouth superior, upper jaw shorter than lower one.
..... *Coregonus albula* species group

2b – Mouth terminal or inferior, upper jaw longer than or equal to lower one.
..... *Coregonus* sensu stricto

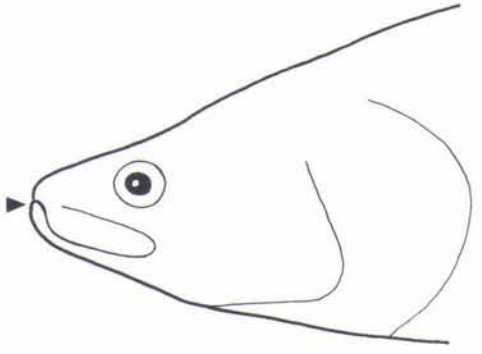

Figure 68 Symphysial knob (arrow) at lower jaw of *Stenodus* species.

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Coregonid systematics: myth and reality

The systematics of Coregonidae is traditionally considered as a nightmare. Most authors appear to have been content simply to mention this complexity as an excuse for not elaborating further on the topic. This resulted in almost all populations of the family being dumped at various times in a 'mythic' catch-all species named *Coregonus lavaretus*, which was stated to be extremely variable and plastic, able to adapt quickly to new habitats and which has evolved into a great number of ecological morphs. A review of the diversity of coregonids shows that this is much exaggerated. In fact the main problem is that coregonid systematics has been complicated by poor or outdated concepts and as a result of the work of scientists who have been unfamiliar with the correct application of the principles of systematics. In addition, the literature is complex, heterogeneous and of very variable quality. Many observations are flawed by ad hoc theories and concepts and by the idea that coregonid systematics has to be different from the systematics of other fishes.

Tradition, the (administrative) fear to have to manage and conserve a significantly larger number of species and their economic value are certainly forces driving some scientists and agencies to close their eyes to, or to seek to negate biological reality and the existence of this taxonomic diversity, or to refuse to give it the same value that a similar diversity would receive had the taxa concerned been birds or African cichlids.

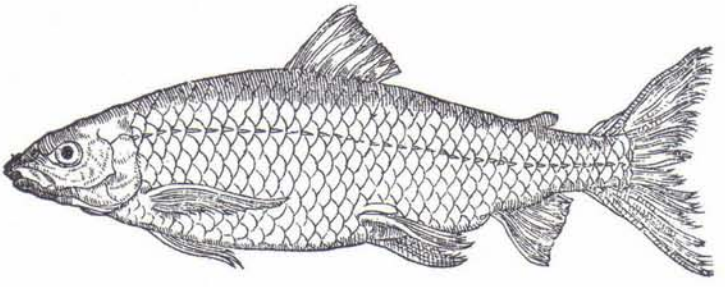
In several lakes, several populations (up to 11 in Lake Onega) are morphologically and genetically distinct, live in sympatry, and have different habitats, ecology, preferred prey and spawning seasons. These populations fit the definition of species, negating the idea that only a single species is involved. In fact, the problem is not so much to recognize the different species, which occur in sympatry in a given water body, but to find out whether or not species in adjacent water bodies are conspecific.

Application of the Evolutionary Species Concept (see Introduction) helps to overcome the conceptual problems. We recognize here 59 species, but the published data indicate that more exist. The published information usually does not permit reasonable conclusions to be reached with regard to the status, identity, and distribution of these species.

This is not to say that identification and systematics of Coregonidae is easy. It is not easy, and this for three main reasons:

- being pelagic and silvery, coregonids exhibit very few salient characters. Benthic fishes usually have a colour pattern or peculiar morphological features (for camouflage and for visual recognition) and our human eyes and brain recognize these characters, thereby helping us to identify the fish. These characters are usually not prominent in pelagic fishes, which use non-visual signals to identify conspecifics.
- differences between sympatric species may be subtle and requires fresh or very well preserved individuals, with information on spawning sites and spawning season.
- introductions and hybridisation have blurred the species limits in several water bodies. Several species are extinct.

At one time, some authors have called most whitefish populations *C. lavaretus*. Others have used the name *C. lavaretus* for one of the Baltic species. Correctly, the name applies only to the species of Lake Bourget (France) where the fish was already reported under the vernacular name 'lavaret' by Guillaume Rondelet in 1555. Its use for any other species is incorrect.



The 'lavaret' from Lake Bourget, as figured in 1555 by Rondelet in his *Universae aquatilium historiae* .

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Coregonus bezola; Lake Bourget, France; the only surviving museum specimen; 183 mm SL.

Rhône drainage (Lakes Geneva, Bourget and Annecy)

At least three species were originally present in Lake Geneva and they are now assumed to be extinct. The only species now present in the lake is *C. palaea*, first introduced from Lake Neuchâtel in 1923. River-spawning individuals are known to ascend the Rhône upstream of the lake for a few kilometres, but it is not known whether they are conspecific with *C. palaea*. Other species have been introduced, accidentally or otherwise, including *C. lavaretus*, *C. maraena*, *C. zugensis*, *C. wartmanni*, *C. peled* and a North American species. Two species were originally present in Lake Bourget; one of them is extinct. The present populations of other lakes of the Rhône drainage seem to be the result of introductions.

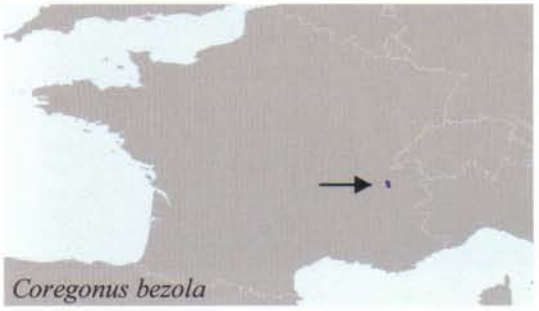
Although part of the Rhône drainage, Lake Geneva has a Rhine drainage fish fauna. A few km downstream of the lake, the Rhône drops by about 25 m through a series of narrow gorges and rapids not passable by fishes. At places the river is only 2 m wide or disappears under large blocks); this dramatic stretch is now flooded by a reservoir. During ice ages, the lake's basin was filled with ice; when glaciers receded the system was first connected to the Rhine and then to the Rhône.
Further reading. Dottrens, 1950.

Coregonus bezola

Common name. Bezoule.
Diagnosis. Distinguished from other species of *Coregonus* in Lake Bourget by: ● 26–33 gill rakers / ○ 81–87 total lateral line scales / ○ back yellowish to brownish, flank silvery with yellowish hue. Size up to at least 320 mm SL.
Distribution. France: Lake Bourget.
Habitat. Lacustrine, in deep waters.
Biology. Spawns in January – February, at 70–80 m depth, on mud bottom.
Conservation status. Extinct*. Disappeared in the 1960s.
Further reading. Fatio, 1888a-b: 1541, 1890: 268 (description); Kottelat, 1997: 104 (systematics).

Coregonus fera

Common name. Féra.
Diagnosis. Distinguished from other species of *Coregonus* in Lake Geneva by: ○ eye diameter 15–19 % HL / ○ 21–28 gill rakers / ○ back slightly arched, dorsal profile of head and snout straight. Size up to 550 mm SL.
Distribution. Lake Geneva (Switzerland, France).
Habitat. Lacustrine, in moderate depth.
Biology. In summer, feeds on insects. Moves to deeper water in winter. Spawns in February in deep water over aquatic vegetation.
Conservation status. Extinct*.
Remarks. Although the name féra is still used for the only coregonid present in Lake Geneva, this is not the original species but the introduced *C. palaea*.
Further reading. Jurine, 1825: 190 (description); Fatio, 1890: 244 (description).



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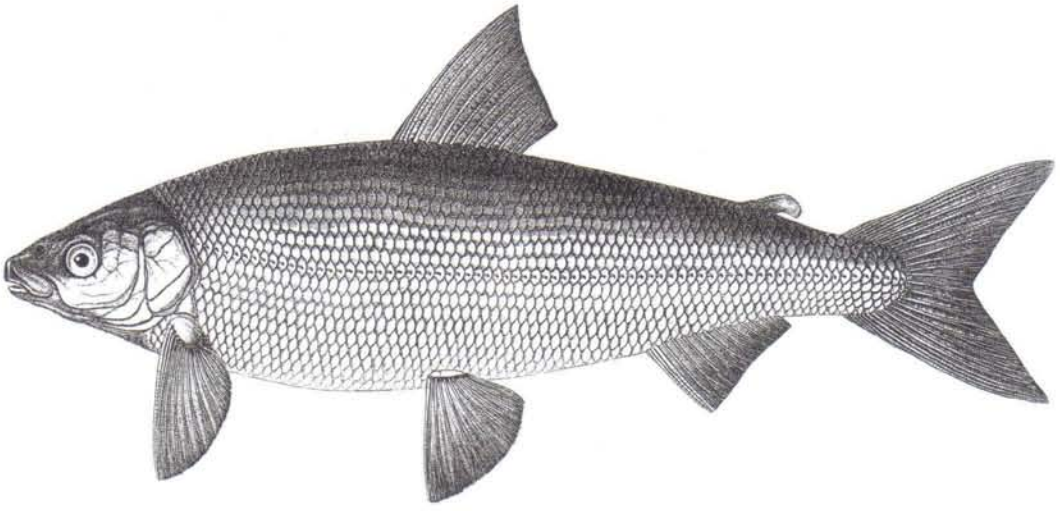
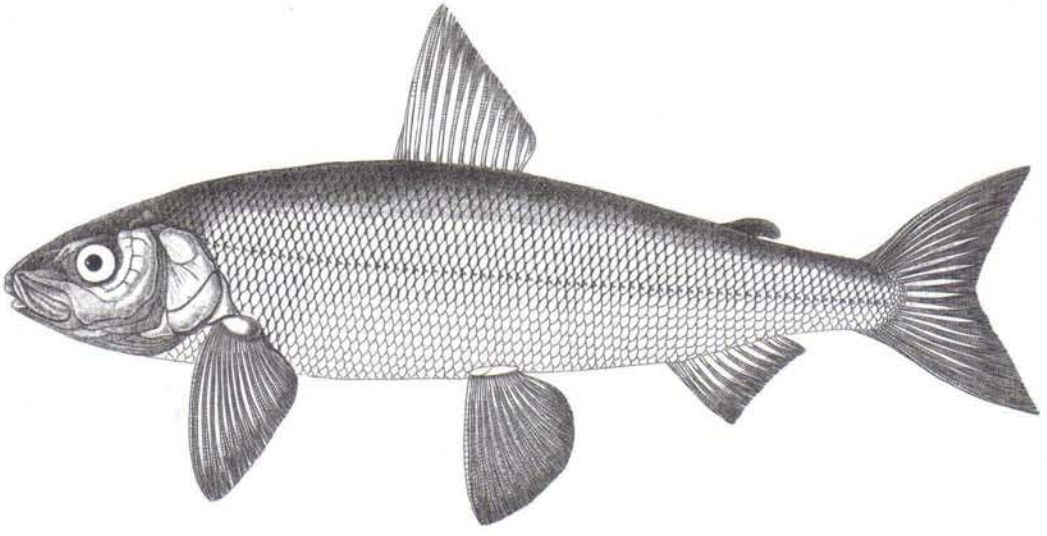
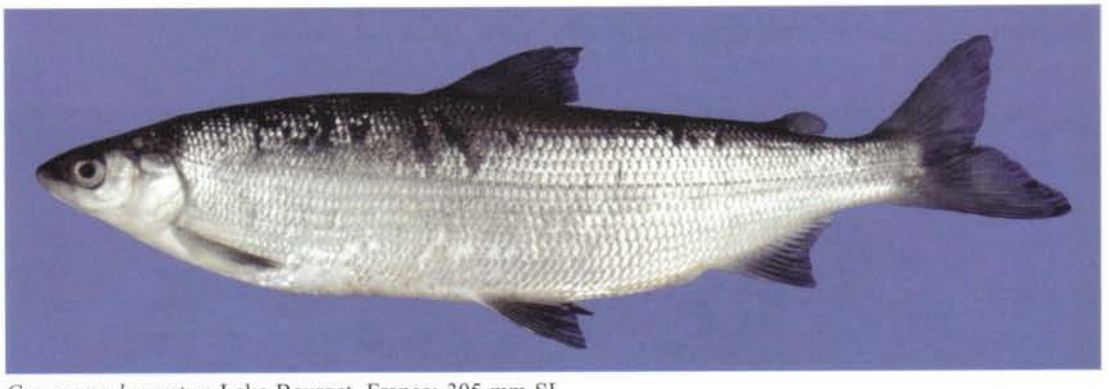


Coregonus fera; Lake Geneva, Switzerland. (from Jurine, 1825)



Coregonus hiemalis; Lake Geneva, Switzerland. (from Jurine, 1825)



Coregonus lavaretus; Lake Bourget, France; 305 mm SL.

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Central European lakes north of the Alps cited in text

	altitude [masl]	area [km²]	depth maximum [m]	depth average[m]
Rhône drainage				
Annecy	447	27	81	41
Bourget	231	45	145	85
Geneva	372	584	310	153
Rhine drainage				
Neuchâtel	429	218	153	65
Bienne	429	40	74	
Morat	429	23	45	
Thun	558	48	215	
Brienz	564	30	260	
Vierwaldstätter	434	114	214	
Zug	413	38	198	
Sempach	504	14	87	
Zürich	406	88	143	
Walenstadt	419	24	144	
Constance	396	539	252	100
Danube drainage				
Attersee	469	46	171	
Mondsee	481	14	68	36
Ammersee	533	47	81	
Traunsee	422	26	191	90
Chiemsee	500	80	73	25

Coregonus hiemalis

Common name. Gravenche.

Diagnosis. Distinguished from other species of *Coregonus* in Lake Geneva by: ○ eye diameter 18–22 % HL / ○ 25–33 gill rakers / ● back arched, dorsal profile of head and snout rounded. Size up to about 300 mm SL.

Distribution. Lake Geneva (Switzerland, France).

Habitat. Deeper parts of the lake.

Biology. In December, moves to spawn in shallower areas, near shore, on gravel.

Conservation status. Extinct*.

Further reading. Jurine, 1825: 200 (description); Fatio, 1890: 261 (description).

Coregonus lavaretus

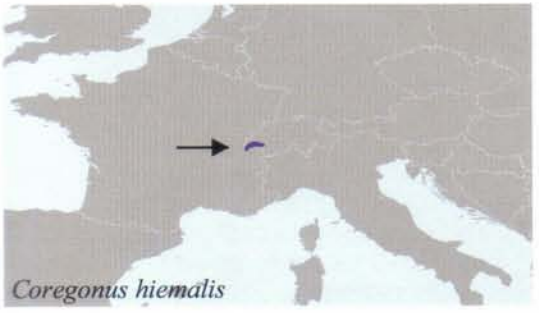
Common name. Lavaret.

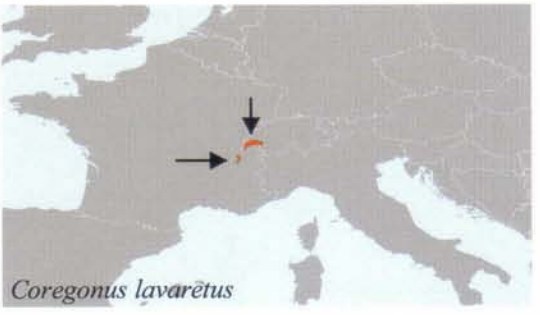
Diagnosis. Distinguished from other species of *Coregonus* in Lakes Bourget and Geneva by: ● usually 33–42 gill rakers / ○ 71–94 lateral line scales / ○ back bluish to bluish green, flank silvery with bluish hue / ○ back slightly arched, dorsal profile of head and snout straight. Size up to at least 400 mm SL.

Distribution. Native to Lakes Bourget (France) and Geneva (Switzerland, France). Population of Lake Aiguebelette (France) apparently introduced, but a 'lavaret' had already been recorded from there in the 17th century.

Habitat. Lacustrine.

Biology. Spawns on gravel, near shore, in shallow water, in December.





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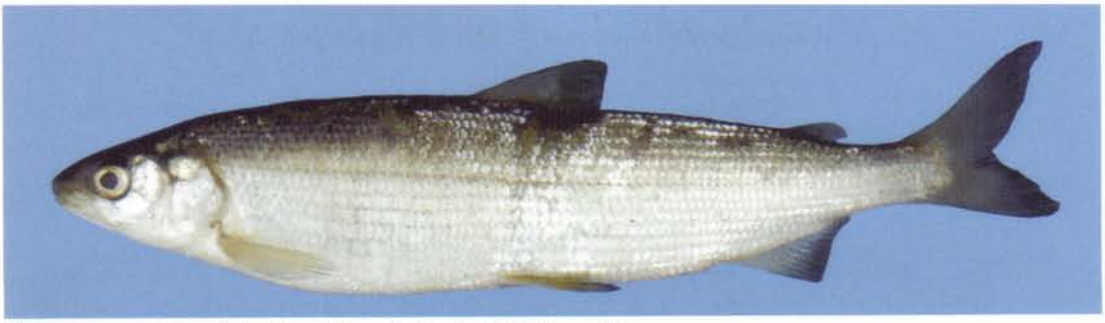
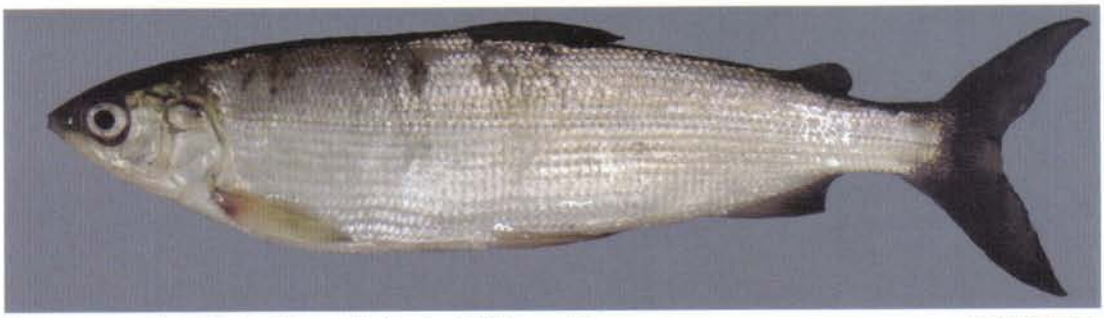


Coregonus candidus; Lake Neuchâtel, Switzerland; 248 mm SL.



Coregonus confusus; Lake Bienne, Switzerland; 270 mm SL. P. Vonlanthen

Conservation status. VU D2. Original population extirpated in Lake Geneva, but as offspring of Lake Bourget population are hatched and reared in Thonon (on the shores of Lake Geneva), escapes should be expected.

Remarks. At some time, the name *C. lavaretus* has been used for about all Eurasian coregonids (and many North American ones). Its use is now restricted to the present species.

Further reading. Fatio, 1890: 138 (description); Dottrens, 1950 (diagnosis); Spillmann, 1958 (Lake Geneva); Kottelat, 1997: 104 (nomenclature).

Lakes Neuchâtel, Bienne and Morat

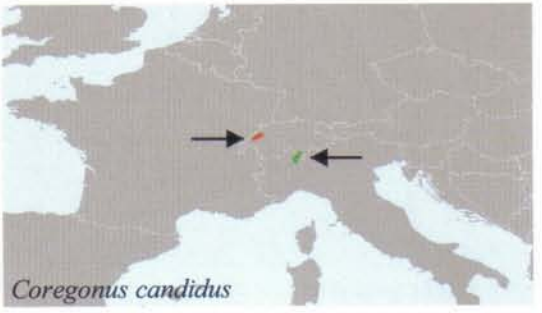
Three species are presently recorded from Lakes Neuchâtel, Bienne [Biel] and Morat [Murten] (middle Aare system, Rhine drainage, Switzerland), but there is indication that an additional species (now extinct) was formerly present in Lake Morat. The original hydrography and environment of the lakes has been much altered by hydrological modifications in 1868–78 and 1962–70 to drain marshes and regulate water levels in the three lakes and connecting rivers. The level of the lakes has been lowered by 2.4 metres and their area decreased by 30 km^2; the course of the Aare was modified to have the river entering and flowing through Lake Bienne. These modifications and eutrophication could be the likely causes of the extinction.

Further reading. Dottrens & Quartier, 1949; Rufli, 1978.

Coregonus candidus

Common name. Bondelle.

Diagnosis. Distinguished from other species of *Coregonus* in area by: ○ 29–39 gill rakers / ○ body slender, back slightly arched, body depth 4.1–4.6 times in SL / ○ head length 4.2–4.7 times in SL / ○ dorsal base 72–100 % of anal base / ○ eye diameter 20–25 % HL / ○ black pigment



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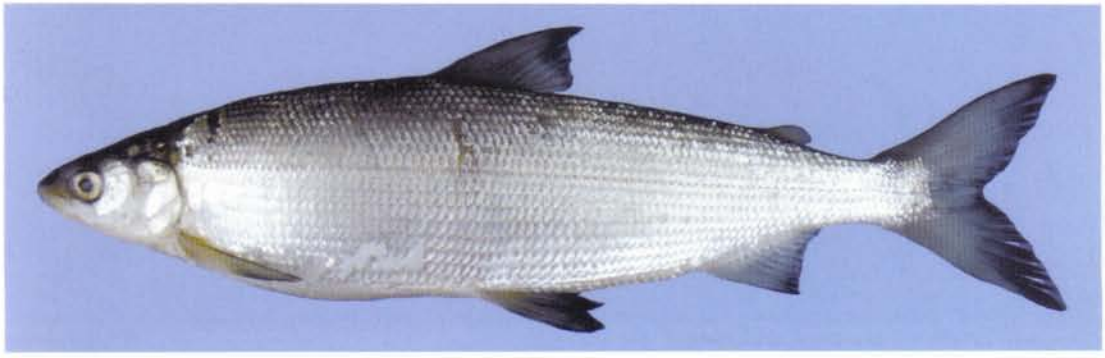

Coregonus palaea; Lake Neuchâtel, Switzerland; 320 mm SL.

usually restricted to tip of pelvic. Size up to about 320 mm SL.
Distribution. Switzerland: Lake Neuchâtel. Introduced in Lake Maggiore (where it has possibly hybridised with other introduced species).
Habitat. Lacustrine, deep waters.
Biology. Males reproduce for the first time at 2–3 years, females at 4. Spawns in January, on sand or mud, in deep water, at depths up to 90–130 m.
Conservation status. VU D2*.
Further reading. Fatio, 1890: 188 (description); Dottrens & Quartier, 1949 (diagnosis); Rufli, 1978 (morphology).

Coregonus confusus

Common name. Pfärrit.
Diagnosis. Distinguished from other species of *Coregonus* in area by: ○ 33–38 gill rakers / ○ back moderately arched, body depth 3.8–4.1 times in SL / ○ head length 4.6–5.1 times in SL. Size up to about 350 mm SL.
Distribution. Switzerland: Lakes Morat and Bienne, possibly also Lake Neuchâtel.
Habitat. Lacustrine, deep waters.
Biology. Spawns in December – January, in Lake Morat on sand or mud at 35–40 m depth, in Lake Bienne on slopes, at 2–20 m depth.
Conservation status. VU D2*. Extirpated in Lake Morat.
Remarks. The bondelle of Lake Bienne is apparently this species. Genetic data suggest that it is distinct from *C. candidus* from Lake Neuchâtel.
Further reading. Fatio, 1890: 132 (description); Rufli, 1978 (morphology); Kottelat, 1997: 105 (systematics); Douglas et al., 1999 (genetics).

Coregonus palaea

Common name. Palée.
Diagnosis. Distinguished from other species of *Coregonus* in area by: ○ 22–32 gill rakers / ○ back moderately arched, body depth 4.2–4.6 times in SL / ○ head length 4.7–5.3 times in SL / ○ dorsal base 97–130 % of anal base / ○ eye diameter 17–21 % HL / ○ black pigment extending on most of pelvic. Size up to about 450 mm SL.
Distribution. Switzerland: Lakes Neuchâtel, Bienne and Morat. Introduced in Lake Geneva and other lakes and reservoirs in France and Switzerland.
Habitat. Lacustrine.
Biology. Males reproduce for the first time at 3–4 years, females at 5. Spawns on gravel near shore or, depending on population, in depths up to 50 m. Spawning time depends on depth and apparently of temperature at that location, from November – December in shallow water to February in deepest places.
Conservation status. LC*. Extirpated in Lake Morat.
Further reading. Fatio, 1890: 235 (description); Dottrens & Quartier, 1949 (diagnosis).

Coregonus restrictus

Common name. Férit.
Diagnosis. Distinguished from other species of *Coregonus* in area by: ○ 35–38 gill rakers / ● body massive, back arched, body depth 3.3–3.6 times in SL / ○ head length 4.4–4.6 times in SL. Size up to about 250 mm SL.
Distribution. Switzerland: Lake Morat.
Habitat. Lacustrine, in deep waters.
Biology. Spawns on sand or mud at 35–40 m depth, in January.
Conservation status. Extinct*.

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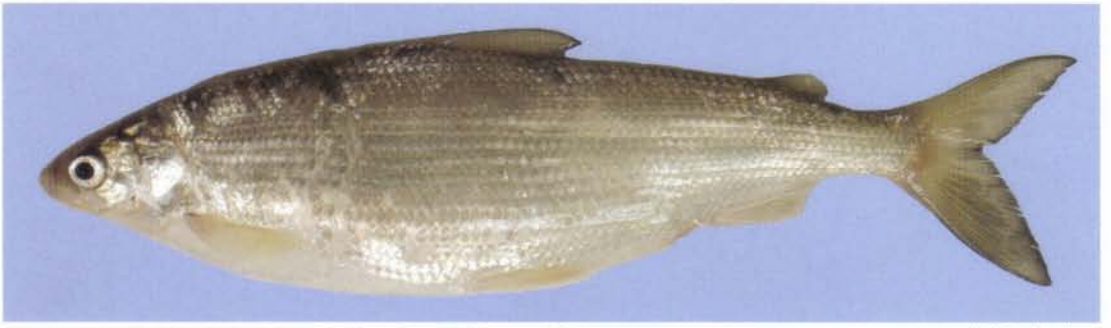
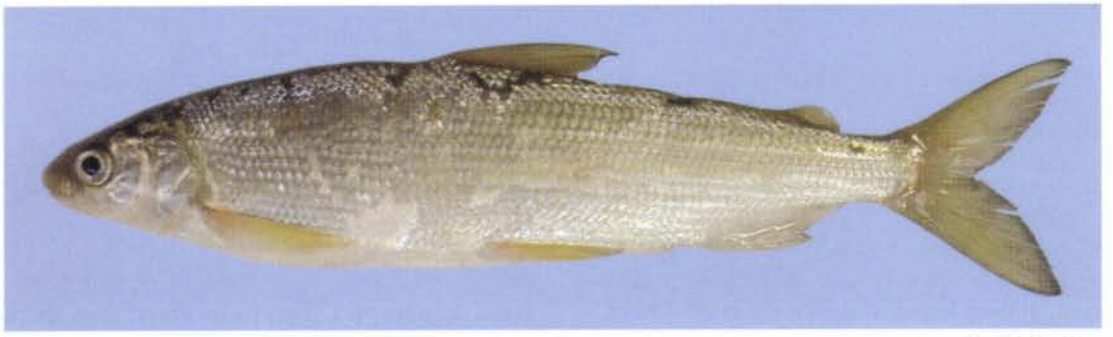


Coregonus albellus; Lake Thun, Switzerland; 240 mm SL. P. Vonlanthen



Coregonus alpinus; Lake Thun, Switzerland; ~210 mm SL. P. Vonlanthen

Further reading. Fatio, 1890: 185 (description); Kottelat, 1997: 107 (systematics).

Lakes Thun and Brienz

There are at least three species of *Coregonus* in Lake Thun (Aare system, Rhine drainage, Switzerland), but this still requires further investigation. It was earlier considered that up to 5 species were present. There have been introductions from Lake Constance in the 1920–30s and genetic studies have recently shown that this introduced species is still present or at least has hybridised with one of the local species. This (and other human impacts) may explain the uncertainties or the observation that spawning seasons and morphology have been altered in the last 50 years. Lake Brienz has three species, two tentatively considered identical with Lake Thun's species, one endemic; a fourth species might be present.

Further reading. Rufli, 1978 (morphology, Lake Thun); Kirchhofer, 1990 (Lake Brienz); Kottelat, 1997: 107 (systematics); Douglas et al., 1999 (genetics).

Coregonus albellus

Common name. Autumn brienzlig.

Diagnosis. Distinguished from other species of *Coregonus* in area by: ○ 35–44 gill rakers (mean 41) / ● fins hyaline or white / ○ eye diameter 18–23 % HL. Size up to about 260 mm SL.

Distribution. Switzerland: Lakes Thun and Brienz.

Habitat. Lacustrine, in deep water.

Biology. Spawns in September, at 30–100 m depth. Spawns for the first time at about 120 mm SL.

Conservation status. LC*.

Further reading. Steinmann, 1950 (biology); Rufli, 1978 (morphology); Kirchhofer, 1990 (bi-

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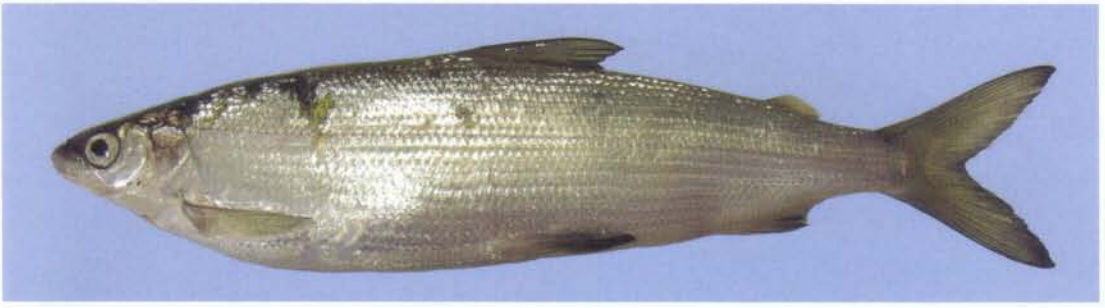

Coregonus fatioi; Lake Thun, Switzerland; 240 mm SL. A. Hudson

ology, Lake Brienz); Kottelat, 1997: 108 (systematics).

Coregonus alpinus

Common name. Kropfer.
Diagnosis. Distinguished from other species of *Coregonus* in area by: ● mouth subterminal / ○ 13–28 gill rakers (mean 20) / ○ eye diameter 20–24 % HL / ○ fins with blackish margin / ○ pectoral fin length 17–23 % SL in individuals larger than 200 mm SL. Size up to about 250 mm SL.
Distribution. Switzerland: Lake Thun.
Habitat. Lacustrine, in deep water.
Biology. Spawns in August – December, at 40–150 m deep, mainly near torrent deltas. Feeds on benthic invertebrates, especially chironomids.
Conservation status. LC*.
Further reading. Steinmann, 1950 (biology); Fatio, 1890: 222 (description; as *C. schinzii helveticus*); Rufli, 1978 (morphology); Kottelat, 1997: 108 (systematics).

Coregonus fatioi

Common name. Albock.
Diagnosis. Distinguished from other species of *Coregonus* in area by: ○ 25–33 gill rakers (mean 29) / ○ eye diameter 20–25 % SL / ○ fins greyish, often with blackish margins / ○ pectoral fin length 14–18 % SL. Size up to about 360 mm SL.
Distribution. Switzerland: Lakes Thun and Brienz.
Habitat. Lacustrine, in midwater.
Biology. Spawns in December, along shores at 0–30 m depth.
Conservation status. LC*.
Remarks. In both Lakes Thun and Brienz, there are forms (?) of this species spawning as deep as 70 m, some with a deeper body. They were reportedly more distinct earlier and had more distinct spawning seasons. The original pattern might have been blurred by hybridisation with introduced species.
Further reading. Steinmann, 1950 (biology); Rufli, 1978 (morphology); Kirchhofer, 1990 (biology); Kottelat, 1997: 109 (nomenclature).

Coregonus sp. winter spawning

Common name. Winter brienzlig.
Diagnosis. Reportedly not distinguishable morphologically from *C. albellus*; distinguished by spawning season and genetic characteristics. Size up to about 270 mm SL.
Distribution. Switzerland: Lake Brienz.

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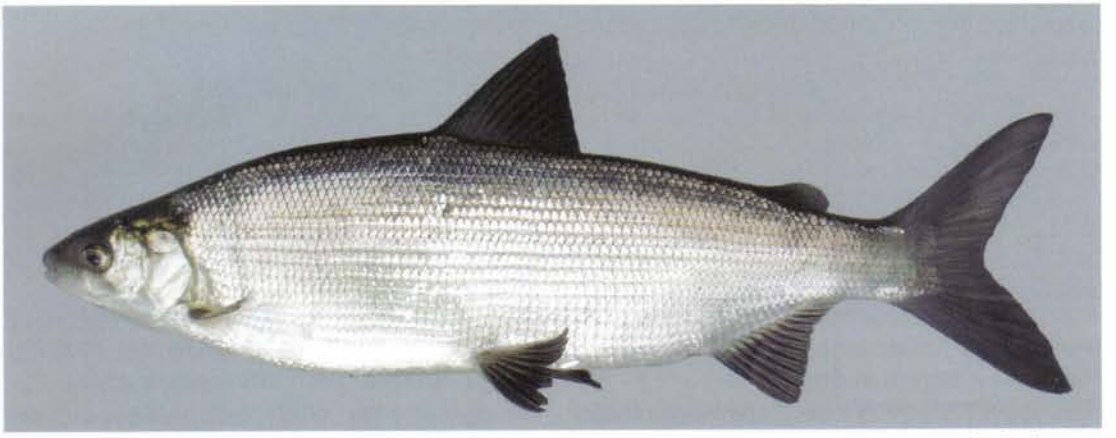
Coregonus nobilis; Lake Vierwaldstätter, Switzerland; 320 mm SL. R. Müller



Coregonus suidteri; Lake Vierwaldstätter, Switzerland; 335 mm SL. O. Seehausen

Habitat. Lacustrine, in deep water.
Biology. Spawns in February – March, at 30–100 m depth.
Conservation status. LC**.
Further reading. Steinmann, 1950 (biology); Rufli, 1978 (morphology); Kirchhofer, 1990 (biology, Lake Brienz); Bernatchez & Dodson, 1994: 246 (genetics).

Lakes of the Reuss system (Vierwaldstätter, Zug, Sempach, etc.)

The status of the different populations from the lakes of the Reuss system (Rhine basin, Switzerland) is still confused. There are apparently three species in Lake Vierwaldstätter. There are apparently two species in Lake Zug and they are tentatively identified as conspecific with two species of Lake Vierwaldstätter. Other smaller lakes in this system seem to host a species, which shows more plasticity than those of the larger lakes and which is very tentatively identified as conspecific with the *C. suidteri* of the larger lakes. Available data also do not allow to decide whether some or all of the species from this system are conspecific or not with those of Lakes Thun and Brienz. Therefore they are conservatively considered as distinct. Alternatively, some of the species might be shared with Lakes Zürich and Walenstadt. To further blur the situation, *C. wartmanni* (and possibly other species) has been introduced from Lake Constance and populations have been transferred from lake to lake (and back) within the system.
Further reading. Steinmann, 1950: 398 (biology); Douglas et al., 1999 (genetics).

Coregonus nobilis

Common name. Edelfisch.
Diagnosis. Distinguished from other species of *Coregonus* in system by: ○ 31–42 gill rakers / ○ eye diameter 3.5–5.2 % SL, 18–21 % HL. Size up to at least 340 mm SL.
Distribution. Switzerland: Lake Vierwaldstätter.
Habitat. Lacustrine, pelagic, feeding at 5–30 m depth.

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Coregonus zugensis; Lake Vierwaldstätter, Switzerland; 160 mm SL. A. Hudson

Biology. In July – September, moves to depths of 80–200 m to spawn. Feeds on crustaceans.
Conservation status. LC*.
Further reading. Fatio, 1890: 146 (description); Birrer & Schweizer, 1935a (biology); Steinmann, 1950: 398 (biology).

Coregonus suidteri

Common name. Balchen.
Diagnosis. Distinguished from other species of *Coregonus* in system by: ● 20–34 gill rakers / ○ eye diameter 3.4–4.5 % SL, 17–21 % HL. Size up to at least 380 mm SL.
Distribution. Switzerland: Lakes Vierwaldstätter, Zug, Alpnach, ? Sempach, ? Baldegg and Hallwil; introduced in Lakes Aegeri, ? Lungern and Maggiore (possibly has hybridised with other introduced species).
Habitat. Lacustrine, feeds on benthic (spring) and pelagic prey (summer).
Biology. Fast growing species. Spawns in November – December, along gravel to stone shores, in very shallow water. Feeds on crustaceans, insect larvae and molluscs. Survival of Lake Hallwil population depends on stocking as eutrophication makes the lake unsuitable for reproduction since 1960.
Conservation status. LC*.
Remarks. The above diagnosis is based on Lake Vierwaldstätter population. Populations from the smaller lakes apparently exhibit a greater variability and their identity requires confirmation. There have been a number of introductions and there are indications that several lakes are now inhabited by hybrid populations and that the original populations or species are extinct. This is probably the case of the original population of Lake Sempach; descriptions of material collected in the 19th century suggest that in fact it might have been a species different from that now present in the lake. Populations from small lakes have also been impacted by eutrophication.
Further reading. Fatio, 1890: 270 (description; Lake Sempach); Birrer & Schweizer, 1938 (as *C. schinzii helveticus* var. *lucernensis*; biology); Steinmann, 1950: 398 (biology); Svarvar & Müller, 1982 (Lake Alpnach).

Coregonus zugensis

Common name. Albeli.
Diagnosis. Distinguished from other species of *Coregonus* in system by: ○ 35–42 gill rakers / ○ eye diameter 4.8–6.5 % SL, 22–28 % HL. Size up to about 200 mm SL.
Distribution. Switzerland: Lakes Vierwaldstätter and Zug. Identity of populations from Lakes Alpnach and Sarnen requires confirmation.
Habitat. Lacustrine, pelagic feeder.
Biology. Most individuals spawn in November – December, at depths of 20–80 m, along littoral slope. In lake Vierwaldstätter, a very rare 'albeli' is spawning in July – August. Its identity needs further investigations. Feeds on zooplankton and insect nymphs.
Conservation status. LC*. Extirpated in Lake Zug.
Further reading. Fatio, 1890: 150 (description);

Coregonus suidteri

Coregonus zugensis

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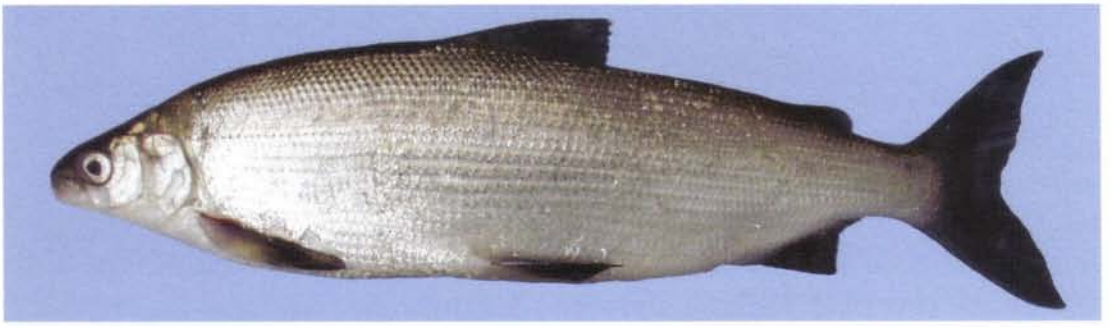
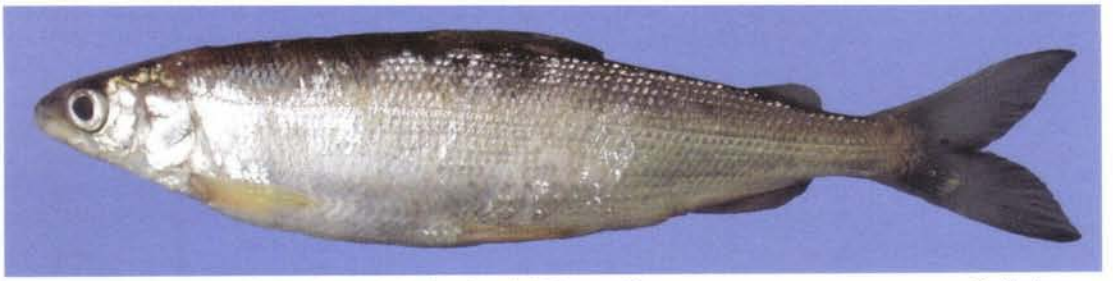


Coregonus duplex; Lake Walenstadt, Switzerland; 370 mm SL. O. Seehausen



Coregonus heglingus; Lake Walenstadt, Switzerland; 190 mm SL. O. Seehausen

Birrer & Schweizer, 1935b (as *C. exiguus albellus*; biology), 1936 (as *C. exiguus albellus*; biology); Steinmann, 1950: 398 (biology).

Lakes of the Limmat system (Zürich, Walenstadt, etc.)

In the middle of 16th century, Gesner already documented the *Coregonus* diversity of Lake Zürich. Nevertheless, among Alpine coregonids, those inhabiting this basin are probably the most poorly known and there is very little data, which can be used to decide how many species there are and what are their identities. Data in the literature suggest that there are a minimum of two and possibly up to four species.

The hydrographic system has been greatly altered by large-scale waterworks in 1807–1822, which had an impact on fish communities and ecology of Lakes Zürich and Walenstadt and reportedly decimated the Walenstadt *Coregonus* populations.

Further reading. Steinmann, 1950: 442 (biology); Ruhlé, 1986, 1988; Kottelat, 1997: 110 (systematics); Douglas et al., 1999 (genetics).

Coregonus duplex

Common name. Grundler.

Diagnosis. Distinguished from other species of *Coregonus* in system by: ● 24–28 gill rakers / ○ 10–12 scale rows between dorsal origin and lateral line and 8–9 between anal origin and lateral line / ● snout blunt / ● back arched. Size up to at least 440 mm SL.

Distribution. Switzerland: Lakes Walenstadt and ? Zürich.

Habitat. Lacustrine, close to bottom.

Biology. Spawns in late November, in very shallow water, over stones close to surf zone. Feeds on snails, worms and insects.

Conservation status. LC*.

Further reading. Fatio, 1890: 252 (description); Steinmann, 1950: 457 (biology).

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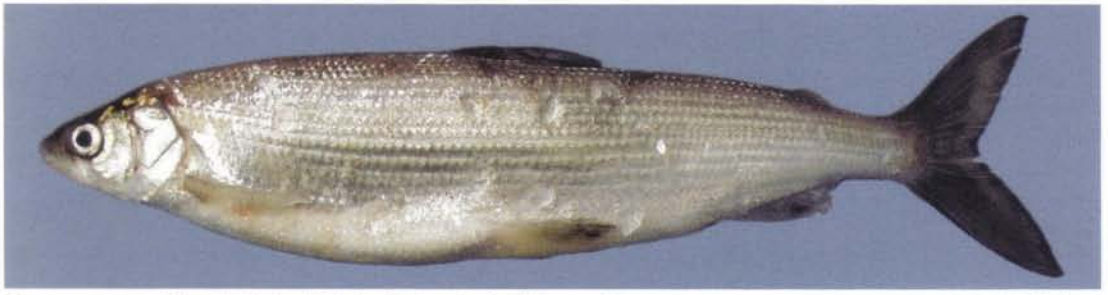

Coregonus zuerichensis; Lake Zürich, Switzerland; 300 mm SL. A. Hudson

Coregonus heglingus

Common name. Hägling.
Diagnosis. Distinguished from other species of *Coregonus* in system by: ○ 29–42 gill rakers / ● 8–9 scale rows between dorsal origin and lateral line and 7–8 between anal origin and lateral line. Size up to about 240 mm SL.
Distribution. Switzerland: Lakes Zürich and Walenstadt.
Habitat. Lacustrine, in deep waters.
Biology. Spawns in July (or until December?) in Lake Zurich, in deep water. Spawns near shores, at depths of 20–80 m, in October – November in Lake Walenstadt. Feeds on plankton in midwater and on benthic invertebrates (snails, chironomids).
Conservation status. DD*. Apparently replaced by a hybrid population in Lake Walenstadt.
Remarks. There is presently a homogenous population in Lake Walenstadt, spawning in October – November. There were reportedly two populations about 50 years ago, one spawning in July – September, one in December – February. The winter-spawning population is said to have appeared in 1899. After the severe environmental problems that impacted the lake at the beginning of the 19th century, it has been hypothesised that displacement of spawning grounds, changes in temperature, and possibly invasion by a species from Lake Zürich resulted in a hybrid population (involving 2 or 3 species), which is now stabilising.
Further reading. Fatio, 1890: 175 (description); Steinmann, 1945, 1950: 457 (biology); Ruhlé, 1986, 1988 (biology; Lake Walenstadt).

Coregonus zuerichensis

Common name. Blaalig.
Diagnosis. Distinguished from other species of *Coregonus* in system by: ○ 27–39 gill rakers / ○ 10–12 scale rows between dorsal origin and lateral line and 8–9 between anal origin and lateral line. Size up to at least 420 mm SL.
Distribution. Switzerland: Lakes Zürich, Walenstadt, Pfäffikon and Greiffensee.
Habitat. Lacustrine, in midwater.
Biology. Spawns in November – December, at depths of 12–100 m. Feeds on plankton.
Conservation status. LC*. Extirpated in Lakes Pfäffikon and Greiffensee.
Further reading. Fatio, 1890: 123, 203 (description); Steinmann, 1950: 443 (biology).

Lake Constance (Bodensee)

Four species have classically been recognized in Lake Constance, one of them now extinct. In addition, two populations might represent distinct species (not listed due to their unresolved taxonomy). There is a population that undertakes spawning migrations in the Rhine in September – November, reaching at least 45 km upriver of Lake Constance; its identity has not been investigated. A potential sixth species (weissfelchen) is very abundant in lower Lake Constance (Untersee). The 'braunfelchen' of upper Lake Constance might belong to the same species. With potentially six species of coregonids, Lake Constance hosts the most diverse central European coregonid fauna. Ecological factors leading to this exceptional diversity have not yet been studied. Molecular data suggest that postglacial Lake Constance was colonized by a single species and that the present species constitute a monophyletic species flock.

Now oligotrophic, Lake Constance began to eutrophicate during the 1950s, with a peak in 1979. Eutrophication has since been decreasing and has now reached about the same level as in 1930. Natural reproduction in coregonids is said to have almost stopped during the period of strongest eutrophication because eggs could no longer de-

Coregonus zuerichensis

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Spawning depth of Coregonidae

Coregonidae exhibit two different spawning modes. Some species migrate to lake tributaries, others spawn in the lake along shores or on shallow places in the lake directly above the bottom. The reported spawning depths of Coregonidae are usually based on fishermen's observations and on the findings of ripe fishes in nets at a precise depth.

In other species (at least *C. wartmanni*), males aggregate at the surface and females ready to spawn come from deeper water to join these aggregations for a few hours and then return to the female groups. The eggs then sink to the bottom. Fully ripe females may concentrate at places or depths different from those at which the spawning act takes place and where males aggregate. Most of the listed spawning depths have to be reviewed very critically. The apparent differences in spawning depths between authors or between different areas for the same species may be real or may result from biased sampling methods.

velop on the low-oxygen substrates. *C. gutturosus* went extinct during this time; stocking of the other species possibly saved them or at least kept their population densities sufficiently high to allow harvesting to continue. Stocking of different coregonids in Lake Constance (especially *C. maraena*) during the first half of the 20th century was unsuccessful. Genitors used to produce fry for stocking were always taken from the lake and from the known spawning sites. As each species has very distinct spawning sites, this protected the genetic integrity of the local species.

Further reading. Wagler, 1941, 1950; Steinmann, 1950; Amann & Kindle, 1992 (Rhine population); Ruhlé & Kindle, 1992 (Rhine population).

Coregonus arenicolus

Common name. Sandfelchen.

Diagnosis. Distinguished from other species of *Coregonus* in Lake Constance by: ○ 18–27 gill rakers / ○ snout blunt / ○ mouth subterminal. Size up to about 550 mm SL.

Distribution. Lake Constance (Switzerland, Germany, Austria). Introduced in lakes of Po drainage (where it possibly has hybridised with other introduced species).

Habitat. Lacustrine, near flat shores, or near bottom, sometimes on steep slopes. Spawns in shallow water, along shores.

Biology. Spawns in late November – December. Feeds on benthic invertebrates (especially mussels, snails, worms and insects).

Conservation status. VU D2*. Has been artificially hybridised with *C. macrophthalmus* and it is not known whether the 'original' species still exist.

Further reading. Fatio, 1890: 229 (description); Wagler, 1941, 1950 (biology; as *C. maraena*, in part); Steinmann, 1950 (biology); Kottelat, 1997: 111 (systematics).

Coregonus gutturosus

Common name. Bodensee kilch.

Diagnosis. Distinguished from other species of *Coregonus* in Lake Constance by: ○ 14–25 gill rakers / ○ snout blunt / ○ mouth inferior. Size up to about 290 mm SL.

Distribution. Lake Constance (Switzerland, Germany, Austria).

Habitat. Lacustrine, in deep water. Spawns in 10–60 m depth.

Biology. Spawns in July – November. After spawning migrates to deeper places, at depths of up to about 140 m. Migrates to 50–60 m in March – April. Feeds on benthic invertebrates (especially mussels and snails).

Conservation status. Extinct*.

Further reading. Fatio, 1890: 254 (description); Wagler, 1941, 1950 (biology; as *C. acronius*); Steinmann, 1950 (biology); Ruhlé & Kindle, 1992 (biology).

Coregonus arenicolus

Coregonus gutturosus

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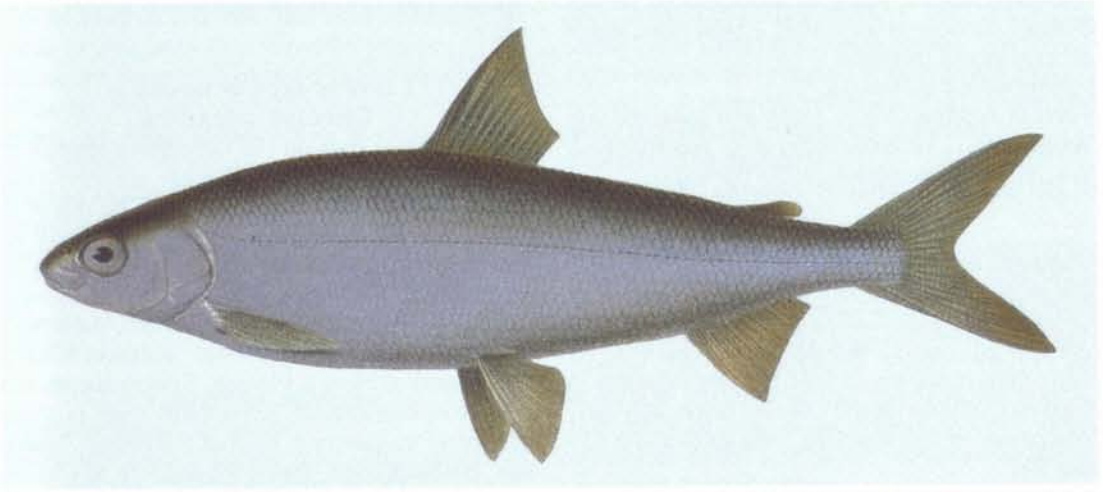
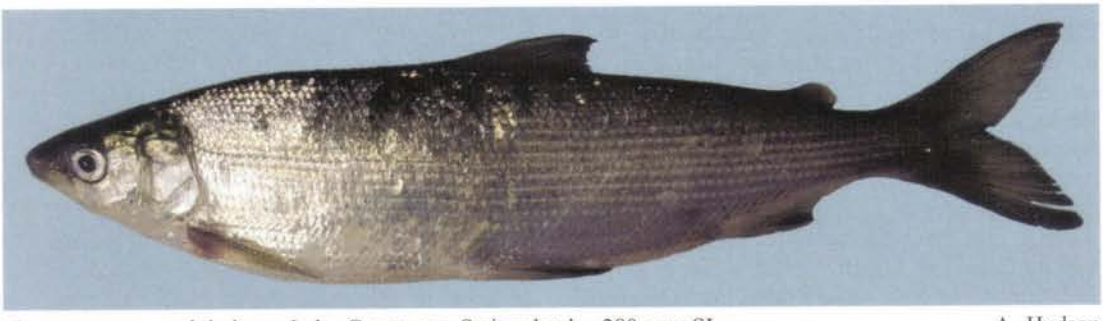
Coregonus arenicolus; Lake Constance, Switzerland; ~500 mm SL. P. Vonlanthen



Coregonus gutturosus; Lake Constance, Germany. (from Vogt & Hofer, 1908–09)



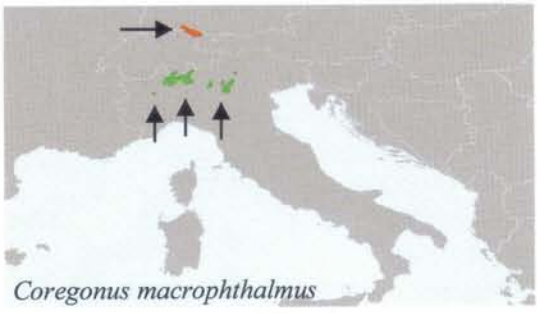
Coregonus macrophthalmus; Lake Constance, Switzerland; ~280 mm SL. A. Hudson

Coregonus macrophthalmus

Common name. Gangfisch.

Diagnosis. Distinguished from other species of *Coregonus* in Lake Constance by: ○ 31–49 long gill rakers / ○ back brownish (character reliable in winter only) / ○ fins whitish, yellowish or reddish. Size up to about 300 mm SL.

Distribution. Lake Constance (Switzerland, Germany, Austria). Introduced in lakes of Po drainage (where it possibly has hybridised with other introduced species) and probably in several other European lakes.



Coregonus macrophthalmus

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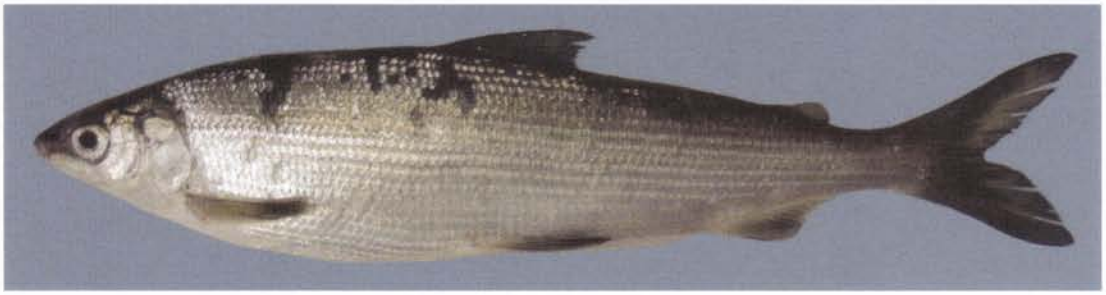

Coregonus wartmanni; Lake Constance, Switzerland; 310 mm SL. P. Vonlanthen

Habitat. Lacustrine, midwater along shores. Spawns in shallow water, on bottom, along shores.
Biology. Spawns in November – December. Feeds on insects and plankton.
Conservation status. LC*.
Further reading. Fatio, 1890: 169 (description); Wagler, 1941, 1950 (biology; as *C. macrophthalmus*, in part); Steinmann, 1950 (biology).

Coregonus wartmanni

Common name. Blaufelchen.
Diagnosis. Distinguished from other species of *Coregonus* in Lake Constance by: ○ 29–46 long and thin gill rakers / ● back bluish (character reliable only in winter, at cold temperatures and in fresh or live individuals) / ○ fins (especially pectoral) more or less blackish. Size up to about 450 mm SL.
Distribution. Lake Constance (Switzerland, Germany, Austria).
Habitat. Lacustrine, pelagic, usually at 0–40 m during summer. Spawns at surface over deep water, off-shore.
Biology. Spawns for the first time at 2–3 years. Spawns in first half of December, when temperature falls below 7°C. Males aggregate at surface and females ready to spawn come from deeper water to join these aggregations. Eggs sink to bottom and hatch in March. Larvae swim to surface and start to feed after about 8 days. Feeds on plankton and insects; preys on juvenile *Perca fluviatilis* in summer.
Conservation status. LC*.

Coregonus wartmanni

Further reading. Fatio, 1890: 115 (description); Wagler, 1941, 1950; Steinmann, 1950: 470 (biology).

Lakes of Danube drainage in Germany and Austria

The published data on the *Coregonus* species of the lakes of the Danube drainage are very confused. Coregonids are considered to be native in 26 lakes in the upper Danube drainage. Almost no information is available for the populations of Wörthersee, Faakersee, Abersee, Obertrumersee, Niedertrumersee, Tachensee, Simssee, Achensee, Wörthsee, Pilsensee, Staffelsee, Riegsee, Eibsee, Weissensee at Füssen, Plansee, Heiterwangsee and Alpsee at Immenstadt. Apparently, there is a single native species in in each of Schliersee, Mondsee, Hallstädtersee, Tegernsee and two in Chiemsee, Traunsee, Ammersee, Starnbergersee and Attersee.

Coregonus from unknown origins were stocked in Irrsee (1968) and Wallersee (1938). *Coregonus* for stocking are farmed in large numbers in Austria and stocked annually in most lakes at least in Austria. Stocked *Coregonus* (28–40 gill rakers, mean 34) are reported to originate from hybrids between the Baltic *C. maraena* and unknown Alpine species. Populations of the stocked *Coregonus* co-occur in some lakes with the native species. In Mondsee, the stocked *Coregonus* is much more abundant than the native *C. atterensis*. In Austrian lakes, the stocked *Coregonus* (called maräne) mature later (more than 3–4 years) and spawn earlier (mid-November to mid-December) than most native species, enabling them to exist in sympatry.

While it seems possible that all native species are still extant, *C. renke* might be most affected because it usually spawns at the same time as the introduced stock. The status of all species is in urgent need of critical review. In most lakes, gill raker counts of the stocked *Coregonus* overlap broadly with those of native species and individuals of the native species of unambiguous identity can only be obtained during peak spawning sea-

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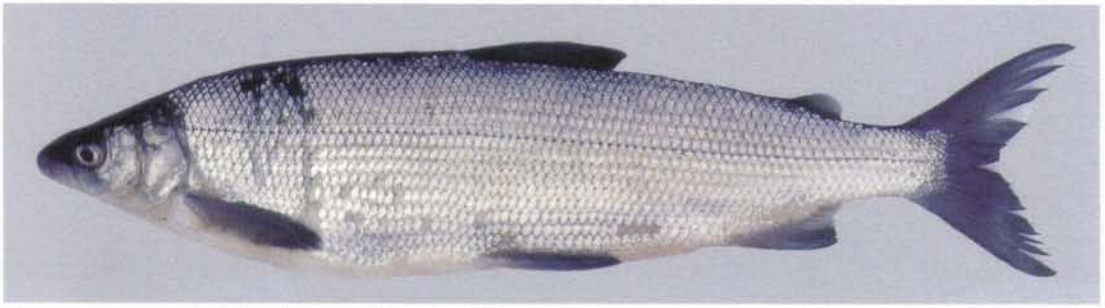


Coregonus atterensis; Lake Attersee, Austria; ~340 mm SL.

son. As the ability to differentiate the local species is more or less lost (this kind of knowledge tends to disappear with the older fishermen), the characters diagnostic of the different species are often not obvious to fisheries biologists and fishermen; the mass occurrence of stocked fish further confuses the situation. In addition, as in many areas in Europe, the diversity of Coregonidae is deliberately ignored or refuted for economic and bureaucratic reasons.

Further reading. Vogt & Hofer, 1909 (biology); Wagler, 1941 (diversity); Kottelat, 1997: 113 (taxonomy).

Coregonus atterensis

Common name. Reinanke.

Diagnosis. Distinguished from other species of *Coregonus* in Danube drainage by: ○ 21–32 (Attersee), 28–32 (Mondsee) gill rakers / ○ pectoral and pelvic dark grey to black in adults / ○ mouth subterminal / ○ snout pointed / ○ adults with greenish brown back / ○ upper jaw reaching at most to anterior eye margin / ○ 73–92 (mean 81) total lateral line scales. Size up to 350 mm SL.

Distribution. Austria: Lake Attersee. A population in Lake Mondsee whose identity still requires confirmation.

Habitat. Pelagic, usually at depths of 10–30 m. Spawns in open water close to surface, above depths of 20–40 m (Attersee) or at 2–3 m and close to shore (Mondsee). Attersee is an oligo-mesotrophic lake and Mondsee a mesotrophic lake.

Biology. Lives up to 6 years (Mondsee). Spawns for the first time at 4 (Attersee) or 3 years (Mondsee). Spawns in early February – mid March (Attersee), late December – mid January (Mondsee). Eggs sink to bottom. Individual fishes usually spawn 2–3 seasons. Feeds on zooplankton and small amounts of benthic invertebrates.

Conservation status. VU D2*. Still present, but seems to be strongly dominated by non-native stocked coregonids.

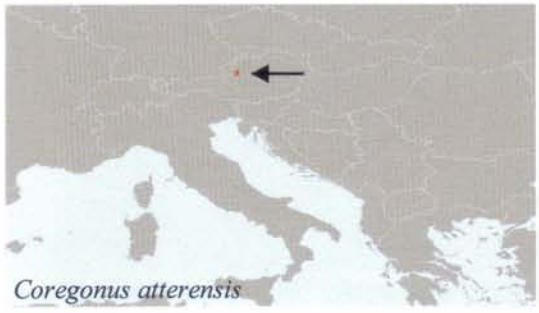
Remarks. In Mondsee, spawns one month earlier than in Attersee. Mondsee population was introduced to Attersee in the early 20th century. After introduction, early spawning individuals were recorded also from Attersee. Further studies are needed to demonstrate that the Mondsee population really belongs to the present species. Today, about half of the *Coregonus* harvested in Mondsee result from stocking.

Further reading. Vogt & Hofer, 1909: 328 (description); Lechler, 1929, 1930b (morphology, biology); Kottelat, 1997: 114 (nomenclature); Wanzenböck et al., 2002 (stocking).

Coregonus austriacus

Common name. Kröpfling.

Diagnosis. Distinguished from other species of *Coregonus* in Danube drainage by: ○ 30–38 (usually 33–35) gill rakers / ○ pelvic and pectoral yellow-hyaline without dark grey tip, yellowish during spawning season / ○ mouth subterminal / ○ snout rounded / ○ back yellowish brown / ○ upper jaw reaching beyond anterior margin of eye / ○ 72–85 total lateral line scales. Size up to



Coregonus atterensis

Coregonus austriacus

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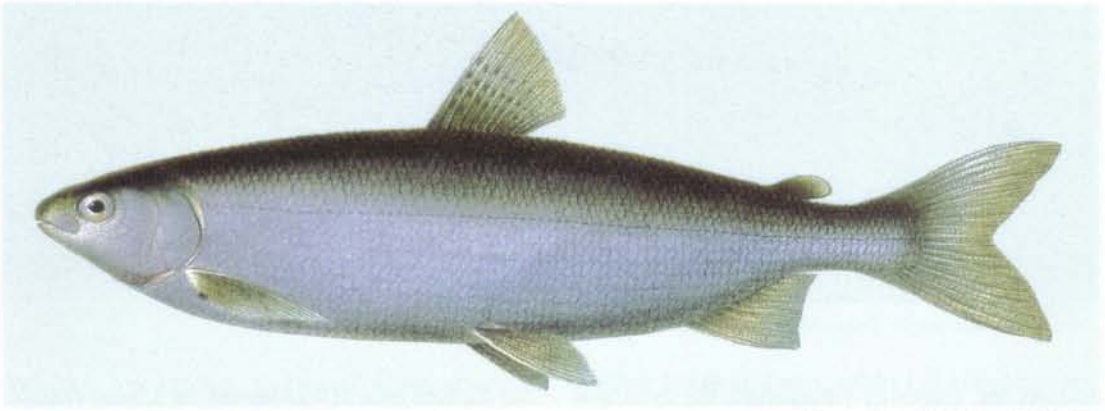
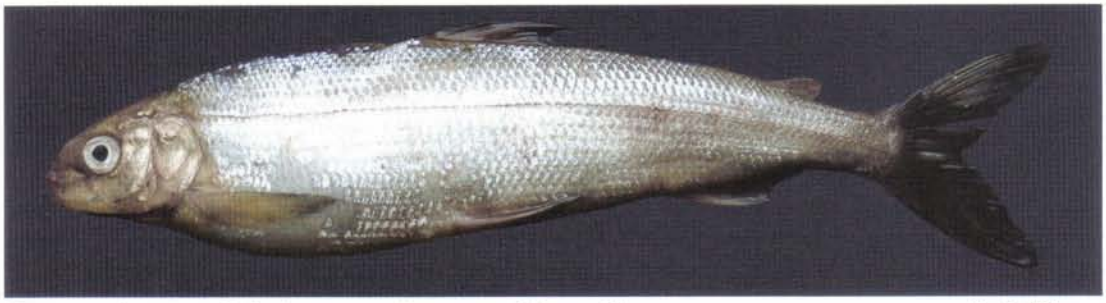


Coregonus austriacus; Lake Attersee, Austria. (from Vogt & Hofer, 1908–09)



Coregonus bavaricus; Lake Ammersee, Germany; ~200 mm SL. U. Schliewen

260 mm SL.

Distribution. Austria: Lake Attersee. Possibly also in Lake Wolfgangsee.

Habitat. Spawns at depths of 80–120 m depth.

Biology. Lives up to 5 years. Spawns for the first time at 3 years, some females at 4. Spawns in last two weeks of December, usually around Christmas. Feeds on deep-water zooplankton as *Daphnia hyalina* and *Bythotrephes longimanus*.

Conservation status. CR B1ab(v)*, stocks sharply declined, not seen in Attersee since at least 2000; no information about Wolfgangsee. Probably on the verge of extinction.

Further reading. Vogt & Hofer, 1909: 330 (description); Lechler, 1930a (morphology, biology).

Coregonus bavaricus

Common name. Ammersee kilch.

Diagnosis. Distinguished from other species of *Coregonus* in Danube drainage by: ● 18–28 (usually 21–24) gill rakers / ○ pectoral short, when folded forward reaching at most to angle of mouth. Size up to 200 mm SL.

Distribution. Germany: Lake Ammersee.

Habitat. At depths of 60–85 m, down to 60 m in summer. Spawns on bottom at depths of 40–50 m. Ammersee is a mesotrophic lake.

Biology. Spawns in June – July, usually between 15 June and 15 July.

Conservation status. CR B1ab(iii) + 2ab(iii). Very rare and declining in Lake Ammersee. Maybe on the verge of extinction.

Remarks. Old literature records 18–21 gill rakers. Published data from the 1930's report 19–28.

Coregonus bavaricus

Coregonus danneri

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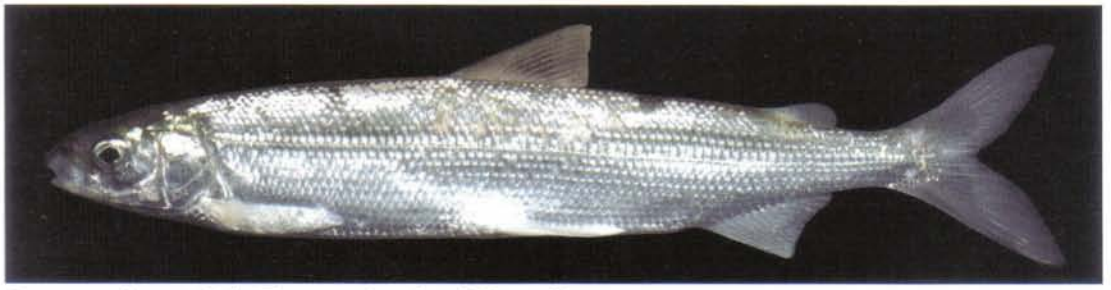

Coregonus danneri; Lake Traunsee, Austria; ~200 mm SL.

The only recently (2003) caught individual was 245 mm SL with 30 gill rakers.

Further reading. Vogt & Hofer, 1909: 332 (description); Freyhof, 2005 (description).

Coregonus danneri

Common name. Riedling.

Diagnosis. Distinguished from other species of *Coregonus* in Danube drainage by: ❍ 30–42 (usually 34–36) gill rakers / ❍ pelvic and pectoral yellow-hyaline or pale grey, usually without dark grey tip / ❍ mouth subterminal / ❍ snout rounded / ❍ back yellowish brown / ❍ upper jaw reaching beyond anterior eye margin / ❍ 76–88 (mean 83) total lateral line scales (vs. 80–99, mean 88 in other *Coregonus* from Traunsee). Size up to 220 mm SL.

Distribution. Austria: Lake Traunsee.

Habitat. At depths of 40–60 m, up to surface in summer. Spawns close to shore. Traunsee is an oligotrophic lake.

Biology. Lives up to 6 years. Spawns for the first time at 2 years. Spawns in mid-October – early March.

Conservation status. VU D2*. Still frequent in Lake Traunsee.

Further reading. Vogt & Hofer, 1909: 332 (description).

Coregonus hoferi

Common name. Schwebrenke.

Diagnosis. Distinguished from other species of *Coregonus* in Danube drainage by: ❍ 24–32 (usually 26–28) gill rakers / ❍ pectoral and pelvic with dark grey to black tip in adults; pelvic (or at least tip) dark grey in juveniles / ❍ mouth subterminal / ❍ snout pointed / ❍ adults with blue back / ❍ upper jaw reaching at most to anterior eye mar-

Lake Traunsee, Austria; habitat of the endemic *Coregonus danneri* and of the regional endemic *Alburnus mento*.

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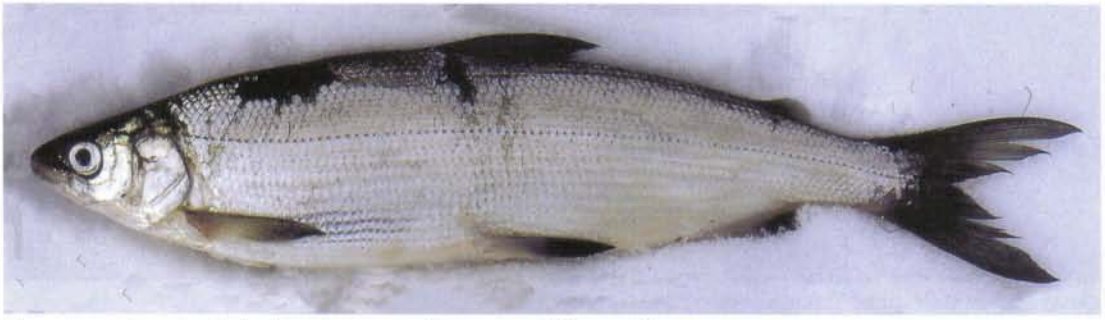
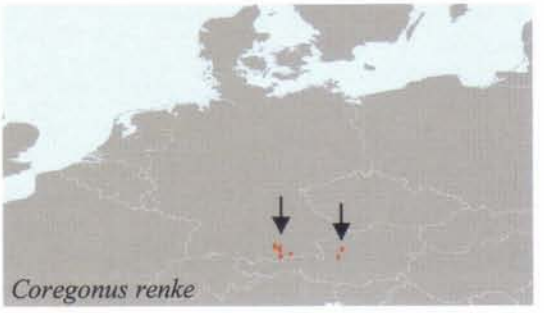


Coregonus cf. *renke*; Lake Starnbergersee, Germany; ~280 mm SL.

gin / ♦ pectoral reaching nares when folded forward (very rarely to snout tip) / ♦ 74–92 (mean 81) total lateral line scales. Size up to 350 mm SL.
Distribution. Germany: Lake Chiemsee.
Habitat. Spawns in shallow water 1–5 m deep, on gravel or rock bottom. Chiemsee is a mesotrophic lake.
Biology. Lives up to 6 years. Spawns in mid-November – early-January, usually in first week of December. Feeds on zooplankton and small insects.
Conservation status. CR B1ab(v)*, probably extinct. Still present in the 1940s. Examined material of the *Coregonus* now present (2004) in Chiemsee all belong to an introduced species.
Remarks. There are indications that a smaller species exists in Chiemsee, spawning at depths of 12–15 m at about the same time. *Coregonus* of unknown origin have been stocked in Chiemsee since 1876.
Further reading. Vogt & Hofer, 1909: 333 (description).

Coregonus renke

Common name. Renke.
Diagnosis. Distinguished from other species of *Coregonus* in Danube drainage by: ♦ pelvic and pectoral with dark grey to black tips (usually hyaline in Ammersee) / ♦ mouth subterminal / ♦ upper jaw reaching at most to anterior eye margin / ♦ 30–40 gill raker (30–40 in Traunsee, 36–38 in Schliersee, 34–35 in Tegernsee, 30–34 in Kochelsee, 30–33 in Starnbergersee, 33–38 in Ammersee). Size up to 290 mm SL.
Distribution. Germany: Lakes Ammersee, Starnbergersee, Tegernsee, Schliersee, Kochelsee; Austria: Traunsee, Hallstädtersee. In 1480, introduced from Kochelsee to Walchensee (not previously inhabited by *Coregonus*).
Habitat. Pelagic in surface layers. Usually spawns above gravel or rocks on bottom or along shores. Spawns below surface in Ammersee. In Traunsee and Hallstädter See, reported to migrate to spawn in tributaries.
Biology. Lives up to 7 years. Spawns for the first time at 3 years. Spawns in late November – early December at 3–4 m depth (Schliersee), in mid December – late January at 10–20 m depth (Tegernsee), in second half of November at 2–3 m depth (Starnbergersee), in mid-December at 80–100 m depth (Kochelsee, Walchensee), in November below surface (Ammersee). Feeds mainly on zooplankton, rarely on benthic invertebrates. May consume large amounts of small fish in summer.
Conservation status. DD*.
Remarks. Several species are possibly confused under the name *C. renke*. In the early 20th century, a small, pelagic feeding species with terminal mouth and 37–44 gill rakers, spawning at the surface in the middle of the lake was present in sympatry with *C. renke* in Starnberger See. It is apparently extinct.
Further reading. Vogt & Hofer, 1909: 337 (description); Kottelat, 1997: 115 (taxonomy).



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Northern Europe (Baltic and White Sea basins)

Northern *Coregonus* are usually placed in two groups, the *C. albula* species group (mouth superior) are known as ciscoes or vendaces and the other *Coregonus* (mouth terminal or inferior) as whitefishes. Only one of these two groups, the whitefishes, forms a monophyletic lineage. We do not treat them as distinct genera but once relationships are better understood and all species analysed, a generic subdivision of *Coregonus* will probably be necessary.

Up to nine species of whitefishes and two ciscoes are reported to co-occur in the same lake (9+2 in Onega, 5+1 in Vänern, 5+2 in Ladoga); most lakes have 2–4 + 1 species. Many species also spend some time in rivers. While the different species in a given lake may be relatively 'easily' distinguished, difficulties arise when trying to equate the species in one lake with those of other lakes. Unfortunately the published information is very disparate. Especially, the morphological descriptions of Scandinavian and Russian stocks are highly insufficient to facilitate definitive identification. Many authors have tended to distinguish coregonids by growth rate and gill raker count. While gill raker counts of millions of individual *Coregonus* have been published, there are only vague statements on morphological features (for example, structure and shape of mouth parts), morphometry or other meristic characters. As a result, very dissimilar populations have been grouped on the basis of their similar average gill raker numbers.

Therefore, it is virtually impossible to extract explicit diagnostic data from the literature. To identify species, the first step is to find out how many species exist in a given water body, to obtain gill raker counts from a large sample, and to blend these counts with data on spawning season (especially its timing relative to other species), feeding habits, maximum size and growth rate. Not surprisingly, without data suitable for a taxonomic analysis, the diagnoses herein can only be vague and unsatisfactory. At the moment, the published data simply do not allow better diagnoses.

The extensive network of lakes of northern Europe is relatively young and dynamic as a result of the glaciation cycles. This instability might have played an important role in the evolution of coregonids and certainly made possible genetic exchanges between many populations, giving rise to a number of species of hybrid origin and probably of multiple hybrid origin. On the other hand, adaptive radiation and formation of monophyletic species flocks at least in the large lakes cannot be ruled out and could change entirely the systems presented here. Recent molecular data suggest the existence of such a species flock in Lake Ladoga (Russia) and Lake Femund (Norway). But, contrary to a frequently repeated axiom, this neither supports nor justifies the conclusion that coregonids cannot be analysed using the usual systematic tools. The species concepts and nomenclatural rules used for all other fish groups are perfectly able to cope with coregonids and species of hybrid origin. The real problem is that experienced taxonomists are not given the possibility (and the funding) to work on coregonid systematics, and that many fisheries agencies are afraid of having to handle a large number of names, which would reflect the actual diversity. It is urgently necessary that coregonid taxonomy be handed over to taxonomists. But this is unlikely to happen in the immediate future and the situation is only likely to become even more confused. It will probably be resolved only when most species are extinct or no longer recognizable because of the creation of unidentifiable hybrid swarms resulting from careless introductions and management.

To revise the systematics of northern European coregonids is clearly beyond the goals of this book (there are some 188,000 lakes in Finland alone!). We by ourselves have had neither the time nor the access to sufficient material for this purpose; we have based our conclusions on the published data and tried to make them consistent. In addition to the incomplete data, problems encountered include differences in methods and concepts used by different workers or in different countries. For Scandinavian stocks, we largely follow Svärdson's (1979) thesis, which is clear when sympatric species of a single lake or drainage are involved, but we ignore the discussions in which taxonomic conclusions are inferred from zoogeographic hypotheses (zoogeographic theories have to be deducted from phylogenetic relationships, not the reverse). Svärdson's concept is based on the assumption that several species invaded northern Europe from Siberia. Recent molecular data suggest that this assumption might be wrong: intralacustrine speciation and adaptive radiation might have given rise to the known diversity from one or two founders. Sympatric coregonid species often are genetically more similar to each other than to morphologically similar populations in other lakes. This may be due to sympatric speciation, but could also result from hybridisation of a species invading an area occupied by earlier arrived (or evolved) species. Therefore, it is still not clear whether the Scandinavian species recognised below and which occur in more than one lake basin are species or artificial assemblages of unre-

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The seven largest European lakes

Lake Ladoga (Russia) has an average depth of 47 m, a maximum depth of 225 m and covers 18,100 km^2. The shores are low and marshy in the south, rocky and indented in the north. Lake Ladoga is a clear, oligo-mesotrophic lake, only slightly polluted by industrial wastewaters. The main tributaries coming from other large lakes connect Lake Ladoga to Lake Onega (River Svir), the Saimaa lake system (River Vuoska) and Lake Ilmen (River Volkhov). The main outlet is River Neva, which flows west into the Gulf of Finland at St. Petersburg.

Lake Onega (Russia) has an average depth of 30 m, a maximum depth of 120 m and covers 9,800 km^2. Its shores are low and sandy in the south, rocky and indented in the north. Lake Onega is an almost unpolluted, clear, oligotrophic lake with dark peat swamp waters. It drains southwest through River Svir into Lake Ladoga. During the last glaciation, today's Lake Onega was partly frozen and situated further south in front of the glaciers draining to the northeast and it had no connection with Lake Ladoga or today's Baltic Sea Basin.

Lake Vänern (Sweden) has an average depth of 27 m, a maximum depth of 106 m and covers 5,560 km^2. Back in the 1970s, Lake Vänern was considered one of the world's most heavily polluted lake, mainly by mercury. The fish had far too high mercury concentrations to be safe to eat. Since, great efforts to clean the lake restored it to an almost oligotrophic state. Lake Vänern is fed by River Klarälven and drained by River Götaälv southwest into the Kattegat.

Saimaa lakes system (Finland) comprises more than 120 connecting lakes, with 13,710 islands, covering 4,380 km^2. It has a maximum depth of 90 m. The Saimaa lakes are mostly oligotrophic and in a natural state. From the Saimaa lakes, water drains trough River Vuoska to Lake Ladoga.

Lake Peipus (Russia and Estonia) has an average depth of 7 m, a maximum depth of 15 m and covers 3,600 km^2. Its shores are shallow and it is situated in a lowland landscape. Lake Peipus is eutrophic and intensively fished. It is fed by River Velikaya and drains to the Baltic Sea.

Lake Vättern (Sweden) has an average depth of 38 m, a maximum depth of 128 m and covers 1,912 km^2. It is oligotrophic, almost unpolluted and has steep, rocky shores. River Forsviksån, which drains Lakes Unden, Viken and Huskvarnaån flows into Lake Vättern, which drains through River Motala to the Baltic Sea.

Lake Inari (Finland) has an average depth of 14 m, a maximum depth of 96 m and covers 1,050 km^2. It is a clear subarctic lake, in an almost undisturbed state. It is fed by River Ivalojoki and empties into the Arctic Ocean through River Paatsjoki.

lated populations. Clearly, one should not attempt to explain the evolution of coregonids with a single scenario paralleled in all lakes of their range; different mechanism are involved, alone or in different combinations, in different drainages. We follow the nomenclature discussed in Kottelat (1997).

Southern Baltic species could reasonably be equated with Svärdson's Scandinavian species. For Russian species, the latest revision is that of Reshetnikov (1980) but his systematic and nomenclatural conclusions are not usable because sympatric populations constituting different evolutionary lineages are treated as conspecific. To have (up to 4!) subspecies of the same species living in sympatry is not acceptable under any species concept. We managed to equate some of the Russian populations with the species recognized here, but only to a limited extent. For the remaining stocks, some seem obviously distinct; for others, we are unable to reach any conclusion and they are not further discussed. This means that the species diversity reported here for Russian waters is certainly below the reality. This is probably true for Scandinavian species as well, for there are indications that some of the species we recognize could be artificial assemblages of several still unrecognized species.

Genetic data show that Alpine species form a lineage distinct from all northern European species (except *C. maraena* from Denmark and maybe elsewhere in western Baltic basin) and therefore it is incorrect to use names of Alpine species for Scandinavian ones. Because of the great difficulties involved in the interpretation of data, no key is given for the northern European whitefishes.

It is obvious that our treatment of the Alpine species is more detailed than that of the Northern European species. This is a clear bias from our greater familiarity with this fauna, the availability of data compatible with a taxonomic analysis, and also language limitation in the assessment of the literature.

The Russian literature commonly uses the shape of the tip of the snout as a diagnostic char-

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Coregonus autumnalis; Kara Sea, Russia; ~400 mm SL. A. Konovalov

acter. The very tip of the snout (called **rostral plate**) is flat and vertical, more or less rectangular when seen from the front (Fig. 69).

Further reading. Nikolski & Reshetnikov, 1970 (Russian species); Svärdson, 1979, 1998 (Swedish species); Reshetnikov, 1980 (Russian species); Bernatchez & Dodson, 1994; Kottelat, 1997 (systematics, nomenclature); Østbye et al., 2005 (Lake Femund).

Coregonus autumnalis

Common name. Arctic omul.

Diagnosis. Distinguished from other species of *Coregonus* in area by: ❍ 35–54 (usually 42–46) gill rakers / ❍ mouth terminal / ❍ snout short / ❍ upper jaw reaching anterior margin of eye / ❍ depth of upper jaw more than 4.0–4.5 times in its length / ❍ rostral plate not developed / ❍ head length 16–20 % SL / ❍ 83–104 total lateral line scales / ❍ body depth 18–24 % SL. Size up to 650 mm SL.

Distribution. All drainages (except Ob and Baikal) of Arctic Ocean in Eurasia from Mezen eastward; America from Cape Barrow to Coronation Bay. Introduced in many localities of former USSR, but not established.

Habitat. Migratory. Mostly larger lowland rivers. At sea, in salinity up to 22 ‰. Northernmost distribution among whitefishes; in summer enters open waters of Kara Sea and reaches Novosibirsk Islands.

Biology. Lives 10–12 years, rarely up to 20. Spends 6–8 years at sea before maturing and returning to rivers in June – July, to spawn in September – October of same year. A second run in autumn; those fishes remain a year in rivers before spawning. Moves far upstream, sometimes up to 1500 km. Spawns in shallow tributaries with some current in well oxygenated water over gravel bottom. Individual females do not spawn every year; spawns only 2–3 times during entire life. After spawning, adults return directly to sea. Embryonic development lasts up to 7 months. Alevins migrate downstream in May – June. At sea, feeds on larger crustaceans and small fish. No feeding during spawning run.

Conservation status. LC. An important commercial species, but catches and abundance markedly reduced in last years.

Further reading. Burkov & Solovkina, 1976: 369 (biology); Reshetnikov, 1980: 189 (morphology); Politov et al., 2002: 39 (genetics).

Coregonus baerii

Common name. Volkhov whitefish.

Diagnosis. Distinguished from other species of *Coregonus* in area by: ❍ 20–29 (usually 24) gill rakers / ❍ mouth inferior, small / ❍ snout short, stout, with a hump at level of nostril / ❍ upper jaw not reaching anterior margin of eye / ❍ depth of upper jaw about 2.5 times in its length / ❍ depth of rostral plate 1.2–1.4 times in its width / ❍ head length 17–20 % SL / ❍ 85–104 total lateral line scales (average 93–94) / ❍ body depth 16–24 %

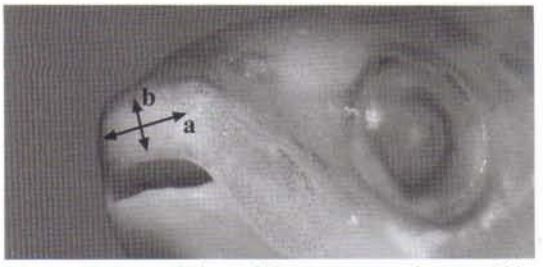
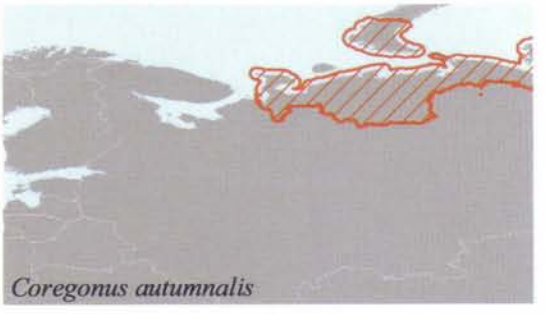


Figure 69 Rostral plate of *Coregonus* species. **a,** width; **b,** depth.



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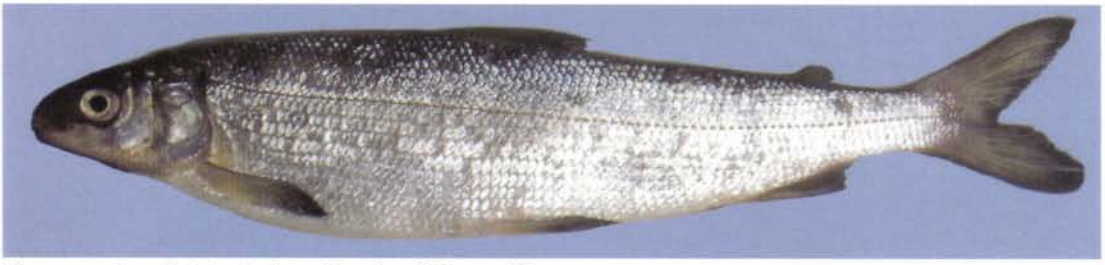

Coregonus baerii; Lake Ladoga, Russia; ~300 mm SL.

SL / ● body fusiform, thick (not compressed). Size up to 570 mm SL.

Distribution. Lake Ladoga, especially southeastern part.

Habitat. Alevins and juveniles mostly occur along eastern shore, adults in deeper places. Used to migrate to River Volkhov up to its uppermost reaches for spawning, now blocked by a dam.

Biology. Lives up to 10 years. Migrates to eastern coast before spawning, starting in May – June. Spawns in October – early November. In Volkhov, used to spawn high upstream, in riffles. Information about spawning in the lake is very sparse, but continued presence confirms lacustrine reproduction. Spawning is now assumed to occur in Volkhov estuary, probably also in lower River Svir. Feeds on benthos (crustaceans, insect larvae, molluscs).

Conservation status. DD*.

Remarks. It is not yet clear whether other coregonids 'forms' are conspecific or not with *C. baerii*. These includes the 'common' Ladoga whitefish (*C. baerii* 'natio ladogae'), the Svir whitefish (*C. baerii* 'natio swirensis') and the Onega whitefish (*C. poljakovi*), which are not included here.

Further reading. Pravdin, 1936: 569 (description), 1954: 62 (description, biology); Shaposhnikova, 1973 (Lake Ladoga; as Volkhov whitefish).

Coregonus holsatus

Common name. Schaalsee maraene.

Diagnosis. Distinguished from other species of *Coregonus* in area by: ○ 23–27 short gill rakers / ○ mouth subterminal / ○ snout not or slightly elongated / ○ upper jaw reaching or almost reaching anterior margin of eye / ○ depth of upper jaw 2.2–3.4 times in its length / ○ depth of rostral plate 6.0–8.3 times in its width / ○ head length 18–23% SL / ○ 86–94 total lateral line scales (average 89) / ○ body depth 17–26 % SL / ○ body considerably compressed / ● eye socket in front of eye markedly triangular (Fig. 70). Size up to about 470 mm SL.

Distribution. Germany: Lakes Schaalsee and Selentersee. Introduced in Lake Drewitz.

Habitat. Lacustrine.

Biology. Spawns in November – December. Feeds on benthic and planktonic invertebrates.

Conservation status. EW*. Extirpated in Lakes Schaalsee and Selentersee. Survives only in Lake Drewitz.

Further reading. Thienemann, 1916: 99 (description).

Coregonus lutokka

Common name. Ludoga.

Diagnosis. Distinguished from other species of *Coregonus* in area by: ○ 20–35 gill rakers (average 23–24 in Lake Ladoga, 30 in Lake Onega) / ○ mouth inferior / ○ snout elongated, rostral plate often rather oblique instead of vertical / ○ depth of rostral plate 0.9–1.2 times in its width / ○ upper jaw reaching beyond anterior margin of eye /

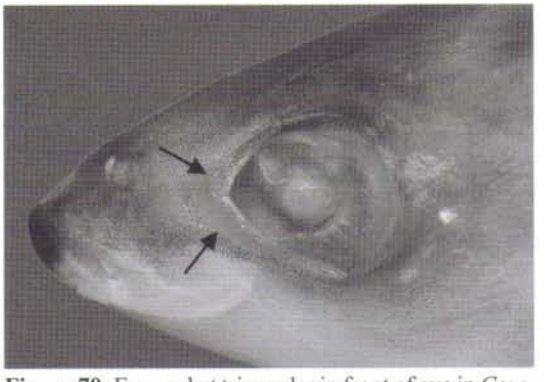

Figure 70 Eye socket triangular in front of eye in *Coregonus holsatus* and *C. widegreni*. The eye socket appears as a translucent tissue (arrows).

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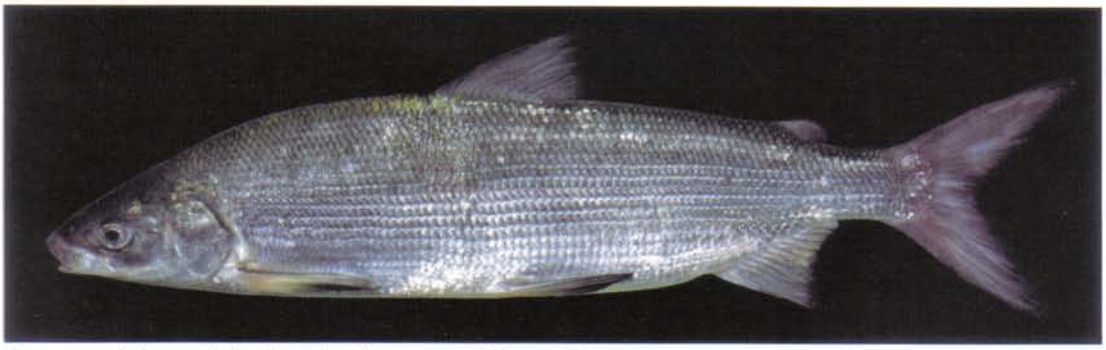
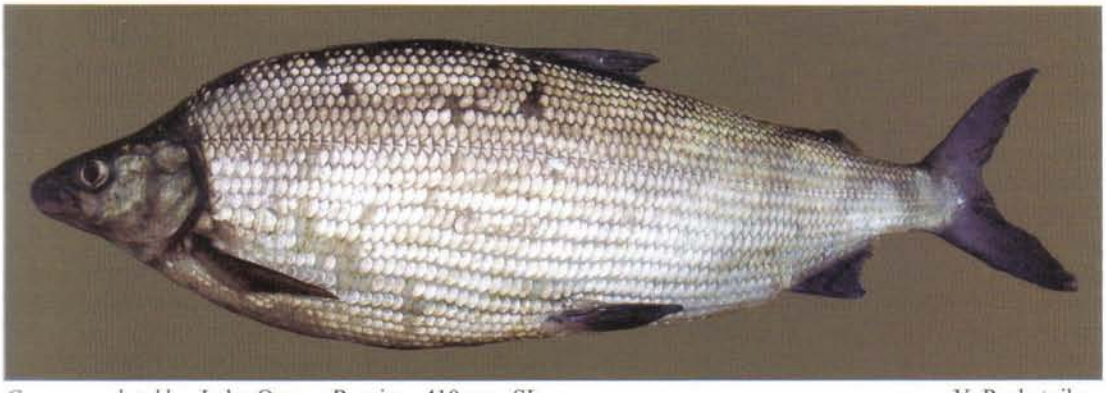


Coregonus holsatus; Lake Drewitz, Germany; ~350 mm SL.



Coregonus lutokka; Lake Onega, Russia; ~410 mm SL. Y. Reshetnikov

○ depth of upper jaw 2.4–2.7 times in its length / ○ head length 17–20 % SL / ○ 83–103 total lateral line scales (average 92) / ○ body depth 19–26 % SL / ○ body considerably compressed. Size up to 600 mm.

Distribution. Lakes Ladoga and Onega, introduced in many natural and artificial water bodies in European and Siberian parts of Russia.

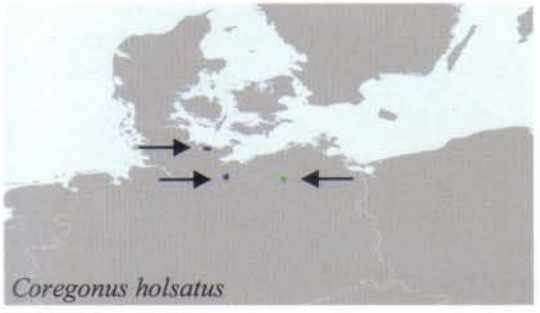
Habitat. In summer, mainly along coasts of southern part of Lake Ladoga, and in winter, along the northern coast. Prefers stone and gravel bottom. No data from Lake Onega.

Biology. Lives up to 10 years. Spawns for the first time at 4–5 years. Forms large aggregations in July – August in a few localities along southern coast of both lakes for intensive foraging, and again in late October – early November (when first ice appears) over stone bottom in southern part of lakes. Spawns during 10–15 days along shores, at a maximum depth of 2 m, on rocks or gravel bottom. After spawning, moves to deeper places to overwinter. Feeds on benthos (insect larvae, molluscs and crustaceans), in summer usually moves to upper water layers to feed on zooplankton, especially Cladocera.

Conservation status. LC*. Most abundant *Coregonus* species in Lakes Ladoga and Onega, with great commercial importance.

Remarks. It is not yet clear whether populations from Lake Onega belong to this species or are part of an endemic species flock.

Further reading. Berg, 1948: 372 (description; as *C. lavaretus ludoga*); Pravdin, 1954: 53 (morphology, biology, distribution); Shaposhnikova,



Coregonus holsatus

Coregonus lutokka

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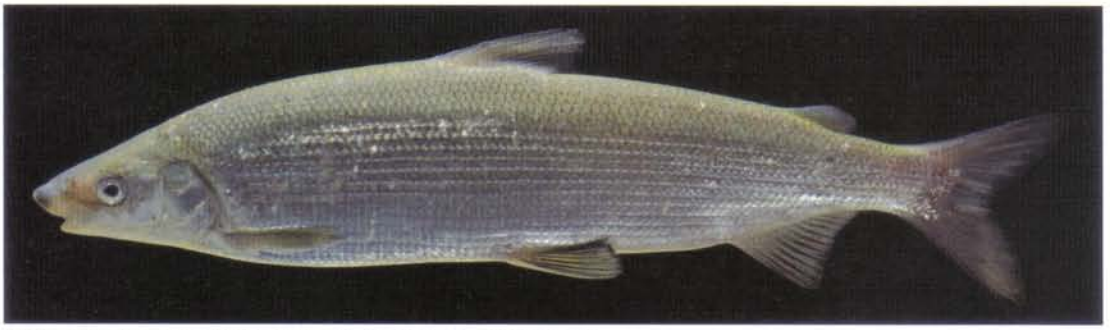


Coregonus maraena; Odra drainage, Germany; ~300 mm SL.

1973 (Lake Ladoga); Kottelat et al., 2005: 183 (nomenclature).

Coregonus maraena

Common name. Maraene.

Diagnosis. Distinguished from other species of *Coregonus* in area by: ○ 20–36 (usually 26–33) gill rakers / ○ mouth inferior / ○ snout elongate at least in males (in landlocked populations of southern Sweden and anadromous populations of the North and Baltic Seas). Size up to about 600 mm SL.

Distribution. Baltic Sea: Swedish coast (including Bothnian Gulf, missing in Gotland); in southern Baltic, extending from River Schlei to Gulf of Finland. Southeastern North Sea basin: Ems, Weser and Elbe drainages and small rivers of Schleswig-Holstein and Denmark. Landlocked in Lake Miedwie (former Madüsee) and other lakes in Poland, Lakes Vättern, Vänern, Mälaren, Siljan (Sweden), Ladoga (Russia) and others. Introduced and transplanted in many drainages within its native range and outside westward to Rhine drainage.

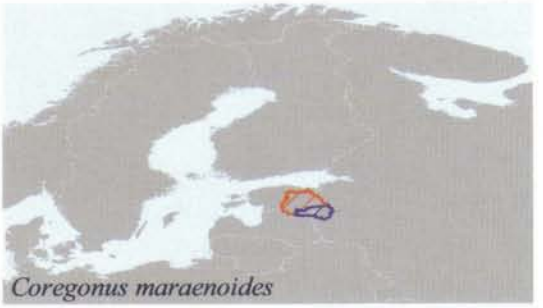
Habitat. Forages along coasts and spawns in freshened parts of estuaries or in lower stretches of rivers. Also in deep, oligo-mesotrophic lakes. Spawns in shallow water, in rapids or small rivers or over firm sediments in lowland rivers and estuaries. In Lake Vänern, spawns at 8–20 m depth, over firm bottom.

Biology. Anadromous and landlocked populations. Spawns for the first time at 3–5 years. Enters rivers in June – October (northern Baltic) or November (southern Baltic), when temperature falls below 10°C. In River Tornionjoki (Finland), individuals ascending from sea in June – August are be distinguished by DNA markers from fish ascending in September. Spawns in October – November (Finland) or December (Poland), when temperature falls below 6°C. Spawners overwinter in river or at sea very close to estuaries. Eggs hatch in early spring (March – April in Odra) and drift to sea or to estuarine bays. Juveniles migrate to sea in June – August (Odra). May migrate up to 700 km from spawning river to forage at sea (Bothnian Bay). Northernmost stocks undertake the longest migrations between spawning and foraging grounds. Some females spawn every second year. Feeds on benthic prey (crustaceans, molluscs, large insect larvae, small fish).

Conservation status. VU A2cd*. Widespread in Baltic basin. Only few natural populations left. Most natural populations declined because of pollution, dams and weirs blocking access to spawning rivers, and overfishing. In Germany, Poland and Scandinavia, apparent abundance only reflects the massive stocking programs without which the populations would rapidly decline. In Gulf of Bothnia alone, about 6 million juveniles were stocked annually in 1995–1998 to support commercial fisheries.

Remarks. Usually known as *C. lavaretus* in Baltic Sea basin. North Sea population might repre-

Coregonus maraena



Coregonus maraenoides

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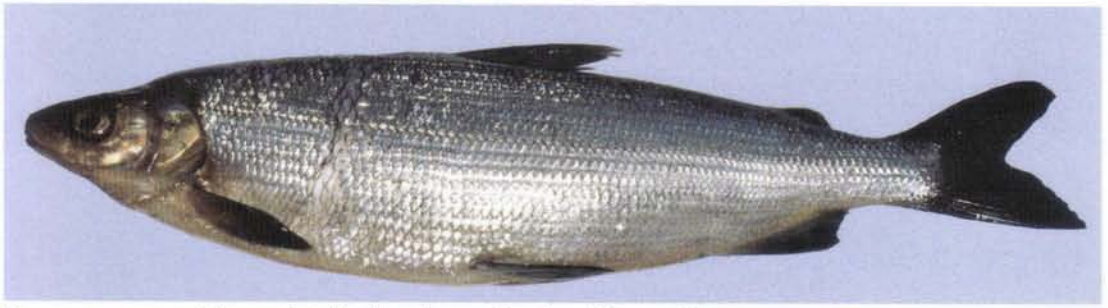


Coregonus maraenoides; market, St. Petersbourg, Russia; ~380 mm SL.

sent a distinct species.

Further reading. Dahr, 1947 (ecology); Svärdson, 1979: 49, 86–87 (as *C. lavaretus*); Heese, 1988 (ecology).

Coregonus maraenoides

Common name. Peipsi whitefish.

Diagnosis. Distinguished from other species of *Coregonus* in area by: ○ 35–45 gill rakers (average 39) / ○ mouth subterminal / ○ lower jaw slightly protruding in larger individuals / ○ snout elongated / ○ upper jaw reaching anterior margin of eye / ○ depth of upper jaw about 3 times in its length / ○ depth of rostral plate about 1.2–1.5 times in its width / ○ head length 18–22 % SL / ○ 84–105 (usually 93–96) total lateral line scales / ○ body depth 24–29% SL in adults / ○ body compressed / ● fins with black margin. Size up to 600 mm SL.

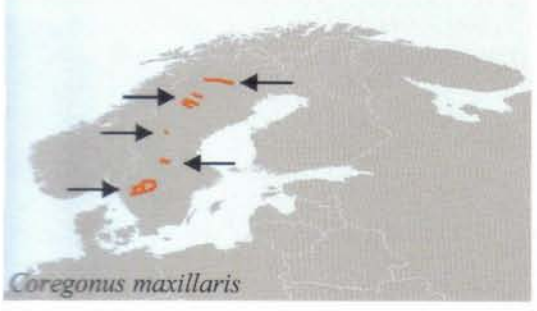
Distribution. Estonia and Russia: Lakes Peipus, Teploe [Lammijarv] and Pskov; enters Lake Wirzjerv [Võrtsjärv] through a connecting river for spawning. Introduced in Lake Burtneck (Latvia), drifted to Gulf of Riga; introduced in many lakes of northern Russia, Poland, Germany, Netherlands, Japan, in lakes in the Urals Region of Russia, Lakes Sevan (Armenia) and Balkash (Kazakhstan), but established only in a few.

Habitat. Lacustrine and riverine. Main spawning sites in southern coastal part of Lake Peipus and northern part of Lake Teploe. Also enters some rivers for spawning.

Biology. Lives up to 15 years, probably longer. Spawns for the first time at 4–5 years. Spawns in October – December, when water temperature falls below 5°C, peaking in late October to early November, under ice, at 1.5–5 m depth. Eggs hatch in late April, at 6–8°C. Feeds mainly on benthic and zooplankton, large individuals also on *Osmerus eperlanus*.

Conservation status. VU B1ab(iii,iv,v); D2*. Population has always been small in Lake Peipus. Populations have declined, now absent in Lake Pskov and sporadic outside Lake Peipus. Earlier regularly stocked, but stocking stopped by the 1990s.

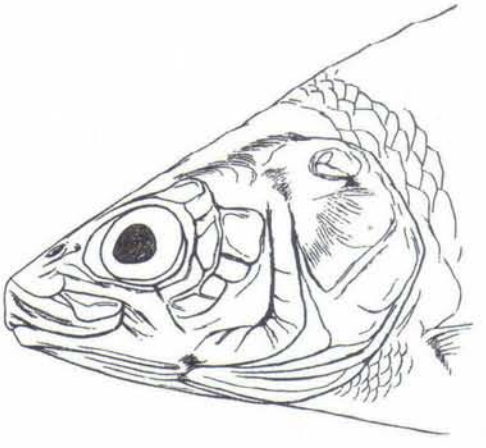
Further reading. Pravdin, 1931: 182 (morphology, biology); Sorokin, 1938: 237 (distribution, biology); Berg, 1948: 385 (description); Krause & Palm, 2000 (biology); Ojaveer et al., 2003: 131 (biology); Kottelat et al., 2005: 183 (nomenclature).



Coregonus maxillaris

Common name. Storsik.

Diagnosis. Distinguished from other species of *Coregonus* in area by: ○ 16–35 (usually 18–23) gill rakers / ○ mouth inferior. Size up to about 500 mm SL.



Coregonus maxillaris, Lake Vänern, Sweden. (from Günther, 1866)

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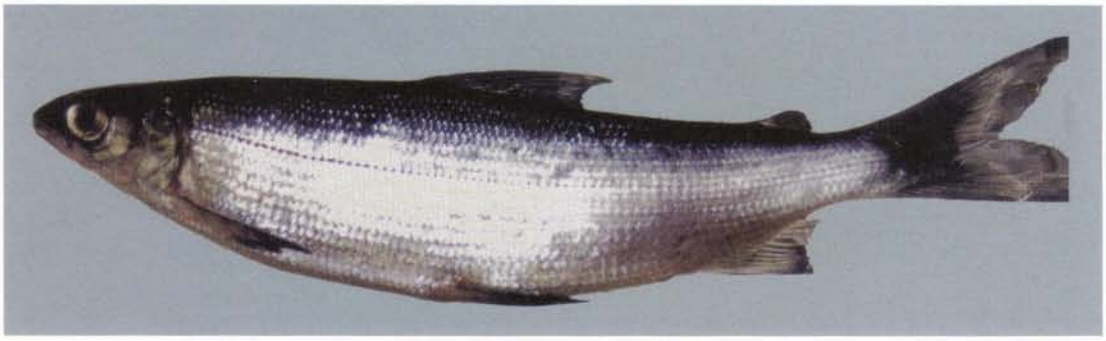
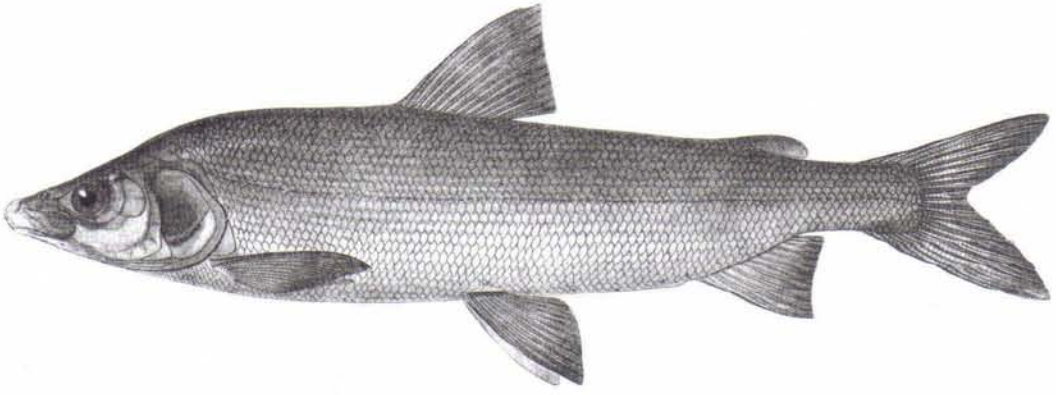


Coregonus megalops; Lake Hoyhainen, Finland; ~200 mm SL. M. Himberg

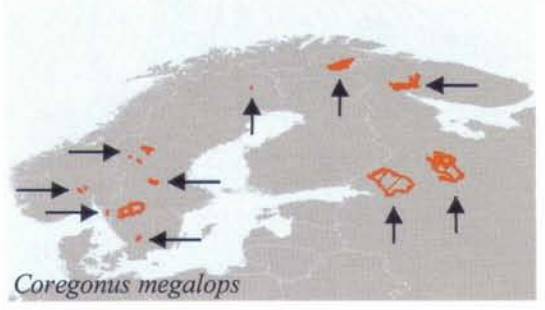


Coregonus muksun; Lena, Russia; 440 mm SL. (from Berg, 1932)

Distribution. Sweden: Lakes Vänern, Locknesjön, Skalka-Parkijaur, Storvindeln, Storlaisan, Storuman, Vojmsjön, Siljan, Övre Särvsjön, Östra Vattnan, Orten-Randsjön, and probably others.
Habitat. Lacustrine, in deeper waters.
Biology. Spawns in October – February, on gravel to stone bottom, at 1–10 m depth. Feeds on benthic invertebrates, especially gammarids, molluscs and insect larvae.
Conservation status. LC*.
Further reading. Svärdson, 1979: 85 (diversity).

Coregonus megalops

Common name. Blåsik.
Diagnosis. Distinguished from other species of *Coregonus* in area by: ○ 26–40 (usually 30–34) gill rakers / ○ mouth inferior / ○ snout elongated / ○ upper jaw reaching anterior margin of eye or slightly beyond / ○ depth of upper jaw about 2.5 times in its length / ○ depth of rostral plate about 1.5 times in its width / ○ head length 17–20 % SL / ○ 85–105 total lateral line scales / ○ body depth 18–27 % SL / ○ body compressed / ● general coloration dark, back sometimes almost black. Size up to 600 mm.
Distribution. Lakes of Baltic and White Sea basins from southern Norway to Karelia and Kola Peninsula (and possibly further eastward), e.g. in Lakes Gruda, Krøtderen, Randsfjorden (Norway), Bullaren, Bolmen, Vänern, Vettasjärvi, Siljan, Storsjön, Tåsjön, Ormsjön, Flåjsön, Övre Särvsjön, Nedre Särvsjön, Östra Vattnan, Orten-Rand-



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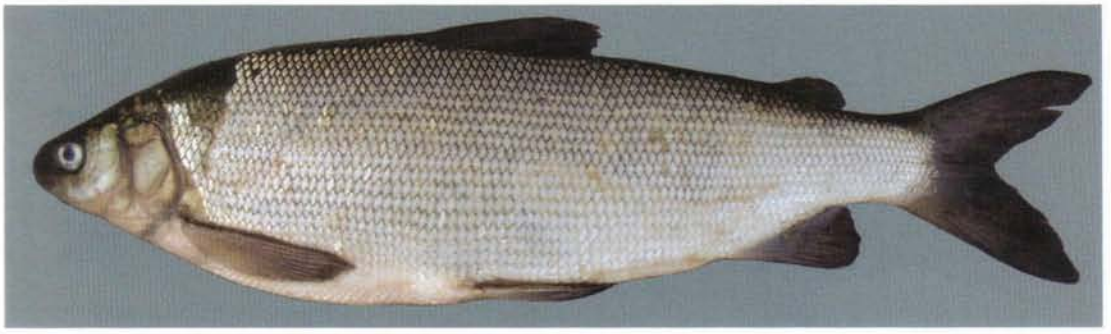


Coregonus nasus; Canada; ~470 mm SL. K. L. Howland

sjön, Ansjön (Sweden), Inarijärvi (Finland), Onega, Ladoga, and Imandra (Russia).

Habitat. Lacustrine. In Lake Ladoga, mainly at depths less than 50 m. Migrates to spawn in bays at beginning of autumn and spawns in November over clean pebble or silt bottom at depths of 2 to 10 m.

Biology. Gregarious, forms shoals. In small lakes and low altitude often sole species of genus. Spawns in September – February, depending on latitude and habitat, in flowing water in mid-autumn, in deep water in winter. In lake Vänern, spawns in November – December, at 2–5 m depth, over gravel or sand. Feeds on plankton in summer, may take benthic prey too.

Conservation status. LC*.

Further reading. Berg, 1948: 363, 377 (as *C. lavaretus mediospinatus*, *C. l. lavaretoides*); Pravdin, 1954 (as *C. l. mediospinatus* natio *musta-siika*, *C. l. lavaretoides* natios *schuensis*, *sunensis*, *lacustris*); Svärdson, 1979: 83 (as blåsik), 1998 (as planktonsik).

Coregonus muksun

Common name. Muksun.

Diagnosis. Distinguished from other species of *Coregonus* in area by: ○ 42–65 gill rakers / ○ mouth inferior / ● snout elongated and shallow / ● head triangular in lateral view and pointed in dorsal view, appearing small and shallow in juveniles compared to deep, hump-backed body in adults / ○ upper jaw reaching middle of eye / ○ depth of upper jaw 3.0–3.5 times in its length / ○ depth of rostral plate 1.5–2.2 times in its width / ○ head length 18–24 % SL / ○ body depth 22–29 % SL / ○ usually 87–94 total lateral line scales. Size up to 900 mm SL.

Distribution. Arctic Ocean basin, from Kara to Kolyma drainages. Introduced or stocked in many lakes in northern and central Russia.

Habitat. Lower reaches of rivers with slow current, large lakes and their tributaries, floodplain lakes, deltas and estuaries, marine waters with salinity up to 6–10‰.

Biology. Anadromous, semi-anadromous, lacustrine, lacustrine-riverine, and riverine stocks are reported. Most stocks are migratory. Spends most of year at sea, sometimes rather far from coast. Enters rivers in July – August and reaches spawning sites by October – November. In larger rivers, moves upriver up to 2000 km (average speed 20 km/day). Spawns for the first time at 6–14 years, 470–500 mm SL. Spawns in rapids or shallows, at 1–2°C, when rivers start freezing. Adults leave spawning sites in winter. Eggs hatch in 150–180 days; peak hatching usually in April. Juveniles feed on planktonic crustaceans. Adults feed on plankton in winter (during which they do not cease active foraging) and benthic invertebrates in summer.

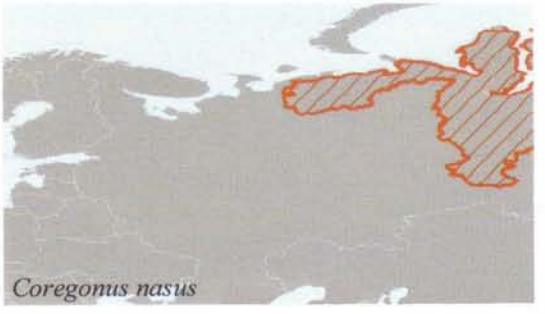
Conservation status. LC. Important commercial species but rapidly declining.

Further reading. Berg, 1948: 411 (biology, morphology); Reshetnikov, 1980: 161 (morphology, biology, distribution).

Coregonus nasus

Common names. Chir, broad whitefish.

Diagnosis. Distinguished from other species of *Coregonus* in area by: ○ 19–24 gill rakers / ○ mouth inferior / ○ snout short, stout, with hump at level of nostril / ○ upper jaw not reaching anterior margin of eye / ○ depth of upper jaw about 2.5 times in its length / ○ depth of rostral plate about 1.5 times in its width / ○ head length 15–20 % SL / ○ 81–98 total lateral line scales /



Coregonus nasus

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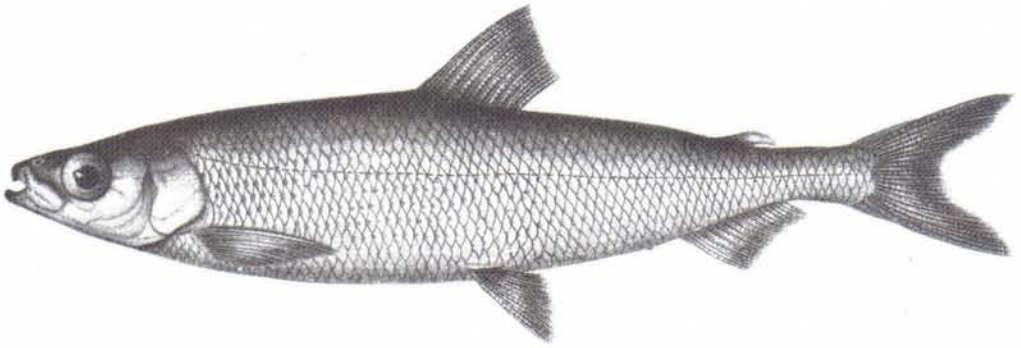
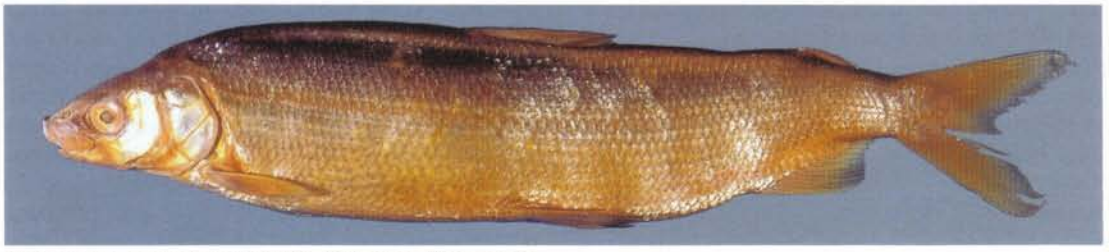


Coregonus nilssoni; Sweden. (from Cuvier & Valenciennes, 1848)



Coregonus oxyrinchus; Schelde, Belgium; 306 mm SL.

O body depth 18–27 % SL / O adipose fin large, length equal to half of anal base. Size up to 610 mm SL.

Distribution. All drainages of Arctic Ocean from Volonga (46°E) and Pechora to Alaska (102°W). Rarely at sea, in water with salinity up to 9–15 ‰.

Habitat. Lowland rivers and lakes.

Biology. Lives up to 15 years. Males reproduce for the first time at 4–8 years, females at 5–9. Adults start upstream migration in late July – August and reach spawning sites by October – November and spawn in stretches with swift current and sand-pebble bottom, often under ice. Spawning lasts 5–7 days and fish leave spawning site soon after, migrating downstream to overwinter in deeper places of lower stretches of rivers together with older juveniles. In spring, alevins drift from spawning sites downstream with flood-water and forage in floodplain lakes and oxbows where they remain until end of summer before moving to river or reaching maturity (if lakes are large enough and do not dry out). Alevins and juveniles feed on zooplankton, adults on benthos, mainly chironomid larvae and molluscs.

Conservation status. LC. Important commercial fish. Widely used for aquaculture in eastern Europe.

Further reading. Reshetnikov, 1980: 166 (distribution, biology); Chereshnev et al., 2001: 119 (morphology, biology)

Coregonus oxyrinchus; Rhine, Netherlands.

Coregonus nilssoni

Common names. Planktonsik, edelmaraene.

Diagnosis. Distinguished from other species of *Coregonus* in area by: O 31–49 (usually 38–46) long gill rakers / O mouth terminal / O dorsal profile of head straight. Size up to 380 mm SL in Polish populations (apparently up to 250 mm SL in Scandinavian populations).

Coregonus nilssoni

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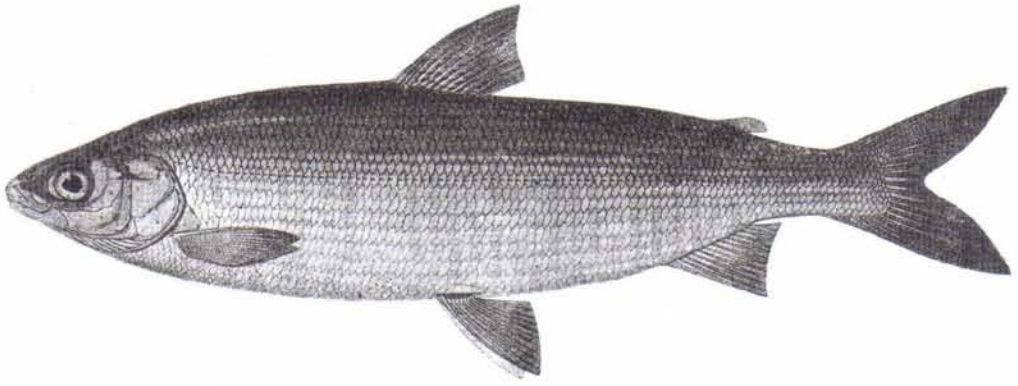


Coregonus pallasii; Neva, Russia; 250 mm SL. (from Pravdin, in Berg, 1932)

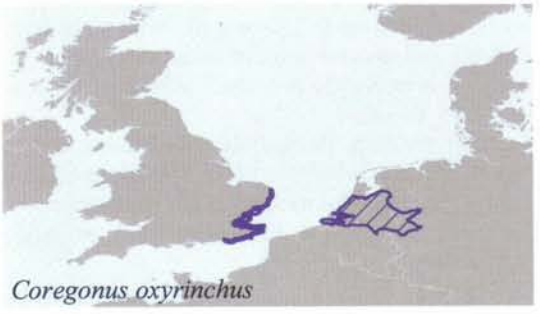
Distribution. Lakes of western central Baltic basin, Sweden, southern Norway, Denmark, lower Odra drainage in Poland. Introduced in some lakes in Poland.
Habitat. Lacustrine, pelagic.
Biology. Spawns in November – March, along shores, at 5–10 m depth, on firm bottom, or in lower part of tributaries. Feeds on zooplankton.
Conservation status. LC*. In Poland, restricted to a few lakes in lower Odra drainage, no data on continued presence.
Further reading. Thienemann, 1928 (Polish populations); Svärdson, 1979: 8, 81 (diversity).

Coregonus oxyrinchus

Common name. Houting.
Diagnosis. Distinguished from other species of *Coregonus* in Europe by: O long, pointed snout / O 36–44 gill rakers / O mouth inferior. Size up to about 470 mm SL.
Distribution. Southern North Sea basin: Schelde, Rhine and Meuse drainages (exceptionally northern France). Ascended Rhine up to Köln [recorded to have reached Strasbourg (France) but this is probably erroneous]. Occasional records from southeast coast of England.
Habitat. In brackish water and main rivers; no evidence that it enters marine waters.
Biology. Spawns in October – December in rivers. Young move to brackish habitats where they remain until mature. Feeds on zooplankton, supplemented by benthic invertebrates in adults.
Conservation status. Extinct* since about 1940.
Remarks. Usually considered to be present in all tributaries of North Sea basin. 'Houtings' from Danish North Sea basin and German rivers from Eider, Elbe west to Ems represent a distinct, possibly unnamed species or belong to *C. maraena*, a species widespread in Baltic basin.
Further reading. Thienemann, 1937 (morphology); Redeke, 1934 (Dutch population); Freyhof & Schöter, 2005 (description, status).

Coregonus pallasii

Common name. Aspsik.
Diagnosis. Distinguished from other species of *Coregonus* in area by: O 32–61 (usually 41–49) long and slender gill rakers / O mouth inferior / O snout elongated / O upper jaw almost reaching anterior margin of eye / O depth of upper jaw about 2.5 times in its length / O depth of rostral plate about 2 times in its width / O head length 19–22 % SL / O 74–96 total lateral line scales / O body depth 21–25 % SL / O body compressed. Size up to 600 mm SL.
Distribution. Large lakes of northern Sweden



Coregonus oxyrinchus

Coregonus pallasii

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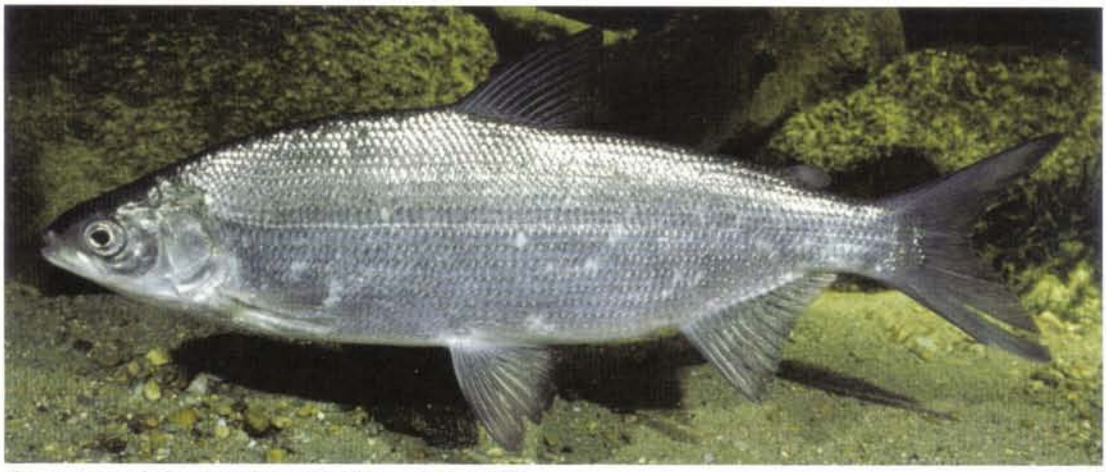
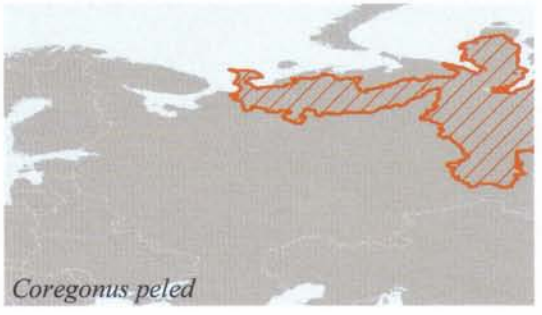


Coregonus peled; aquaculture, Czechia; ~350 mm SL. A. Hartl

(Parkijaure, Hornävan, Storlaisan, Storuman, Vojmsjön, Storlögdan), Finland and Russia (Karelia). Only sporadically in Baltic near Neva and Narva estuaries.
Habitat. Lacustrine. Often enters rivers to spawn.
Biology. Spawns in October – November, on gravel to stone bottom, near shores. Feeds on zooplankton and insects from surface.
Conservation status. LC*.
Further reading. Berg, 1948: 415 (as *C. muksun aspius*); Pravdin, 1954 (description); Svärdson, 1979: 17, 79–81 (diversity).

Coregonus peled

Common name. Peled.
Diagnosis. Distinguished from other species of *Coregonus* in area by: ● head and dorsal with small black spots / ○ 46–69 (usually 53–65) gill rakers / ○ lower jaw slightly protruding / ○ snout short / ○ upper jaw reaching anterior margin of eye / ○ rostral plate not developed / ○ 76–104 (usually 87–90) total lateral line scales / ○ body depth 22–31 % SL in adults. Size up to about 500 mm SL.
Distribution. Russia: Arctic Ocean basin from Kolyma (eastern Siberia) westward to Mezen drainages. Hybrids involving *C. peled* introduced in many reservoirs and lakes (e.g. Onega) throughout Russia, and eastern and central Europe.
Habitat. Lakes and rivers.
Biology. Lives up to 13 years (6 in dwarf form). Different populations of different forms greatly differ in growth rate. Spawns for the first time at 3–6 years, males one year earlier than females. Females ripen very fast just before spawning; most females spawn each year. Spawns in autumn – early winter depending on local climate, over hard sand (shallows in lakes), sand, gravel or stone bottom (in rivers). In northern lakes, spawns under ice. Depth at spawning sites depends on ice thickness and changes in water level, commonly 1–3 m. Spawning lasts 12–16 days at 2–3°C. Feeds on zooplankton (mostly crustaceans), benthic animals (especially insect larvae and mussels, also algae) and insects from surface.
Conservation status. LC.
Remarks. Record from Sweden (lake Storvindeln) apparently is *C. pallasii*. Russian authors recognize 4 groups of populations, which partly occur in sympatry and which seem to be distinct species: 1) river peled; living in river, spawning in river, extending from Mezen to Yenisei drainages; 2) lake-river peled; in same drainages but absent from Ob River; 3) large lacustrine peled; spawning in lakes, reaching up to 440 mm SL; 4) dwarf lacustrine peled; living and spawning in lakes, reaching up to 250 mm SL, with a shallower body and several rows of small black spots on body. It is presently not clear, which of them is the 'true' *C. peled*.
Further reading. Berg, 1948: 347 (morphology); Nikolski & Reshetnikov, 1970: 256 (systematics); Reshetnikov & Mukhachev, 1989: 9 (distribution, biology); Svärdson & Filipsson, 1994 (presence in Sweden).



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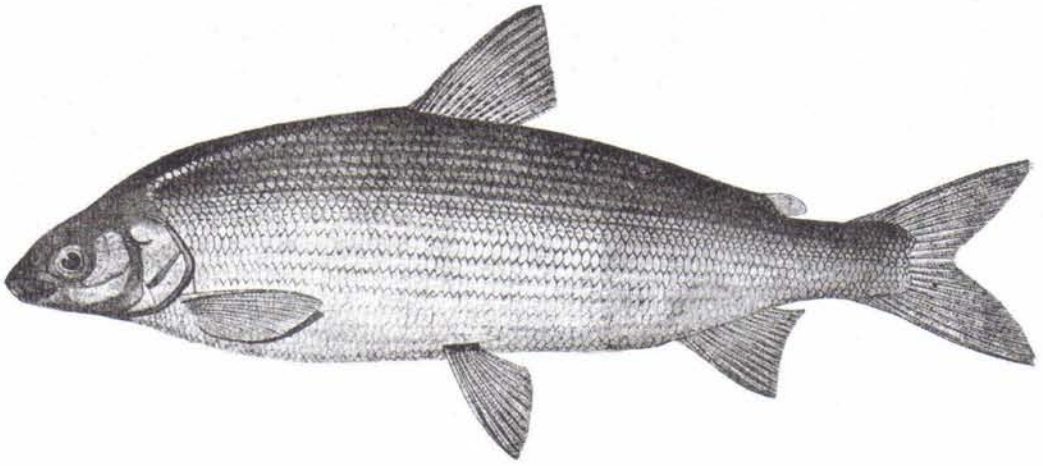


Coregonus pidschian; Amur, Russia; 290 mm SL. (from Berg, 1932)

Coregonus pidschian

Common names. Arctic whitefish, pidschian.

Diagnosis. Distinguished from other *Coregonus* in Scandinavia and Russia by: ○ 15–30 gill rakers (in Europe usually 19–29) / ● length of lower jaw 5–7 % SL, usually 82–90 % of depth of caudal peduncle (which is 8–9 % SL) / ○ mouth inferior / ○ snout short, rounded, with slight hump at level of nostril / ○ upper jaw reaching anterior margin of eye / ○ depth of upper jaw about 3 times in its length / ○ depth of rostral plate about 1.5–1.8 times in its width / ○ head length 17–20 % SL / ○ 70–99 total lateral line scales (average 90–94 in northern European Russia) / ○ body depth 19–26 % SL in adults / ○ body compressed. Size up to 500 mm SL.

Distribution. Arctic Ocean basin, from Finland (Lapland) to eastern Siberia, Alaska, and Canada eastward to Mackenzie drainage.

Habitat. Lower reaches of rivers with slow current, large lakes with tributaries, floodplain lakes, deltas and estuaries, brackish waters.

Biology. Males reproduce for the first time at 4–7 years, females at 5–8. Migratory. In July – August, congregates in large schools and migrates upriver to spawning sites. Lacustrine-riverine stocks enter lake tributaries. Distance of migration varies, commonly not very long. Most individuals spawn annually in August – November, sometimes later, in smaller streams or shallows of larger rivers with heavy current over gravel or stone bottom. Lacustrine stocks not migratory. Female lays only a single portion of eggs. Adults migrate downriver to deeper holes of middle stretches to overwinter. Usually starts downstream migration to feeding areas with ice melting. Feeds mainly on large benthic invertebrates (molluscs, gammarids, mysids, chironomids) and plankton in summer, small fishes and terrestrial insects in autumn.

Conservation status. LC*. Due to human impact and overfishing some populations have declined.

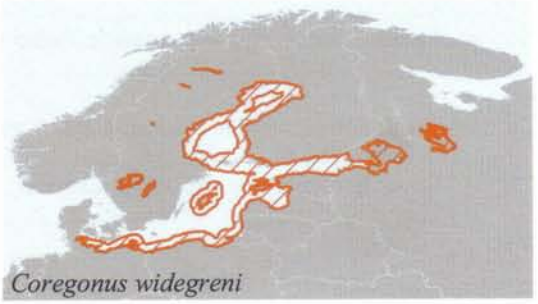
Further reading. Pravdin, 1954: 297 (morphology, biology); Shaposhnikova, 1974 (biology); Reshetnikov, 1980: 175 (biology); Kaukoranta et al., 2000: 24 (biology; as *C. lavaretus fera*).

Coregonus widegreni

Common names. Valaamka, Sandsik.

Diagnosis. Distinguished from other species of *Coregonus* in area by: ○ 16–34 (usually 21–32) short gill rakers / ○ mouth clearly inferior /

Coregonus pidschian



Coregonus widegreni

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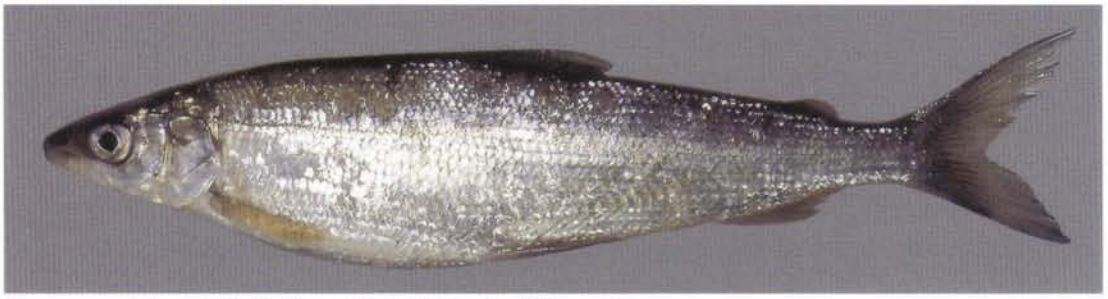

Coregonus widegreni; Baltic Sea at Oulu, Finland; ~200 mm SL.

○ snout elongated / ○ upper jaw reaching anterior margin of eye / ○ depth of upper jaw 2.5–3.0 times in its length / ○ depth of rostral plate 1.2–1.4 times in its width / ○ head length 17–24% SL / ○ 82–100 total lateral line scales (average 92) / ○ body depth 17–26 % SL / ○ body considerably compressed / ● eye socket in front of eye markedly triangular (Fig. 70). Size up to about 550 mm SL.

Distribution. Baltic: Bothnian Gulf, Gotland (missing along Swedish coast southward of Stockholm); southern Baltic: from Germany to Gulf of Finland; several landlocked populations in Sweden (lakes Vänern, Vättern, Locknesjön, Storvindeln, Storlaisan, Skalka-Parkijaur, Arjeplog) and Russia (Neva drainage, Lakes Ladoga and Onega).

Habitat. At sea, coastal waters. Lacustrine, at depths greater than 30 m, in Lake Ladoga commonly at 50–150 m.

Biology. Anadromous and landlocked populations. Lives up to 20 years. Spawns for the first time at 4–6 years. In northern Baltic, spawns along shores or in lowermost stretches of rivers, in October – January. In Lake Ladoga, spawns at 50–100 m depth, in late November – December (later than other sympatric *Coregonus* species), overwinters in deep water and moves to higher water layers (25–40 m) only in summer. Feeds on benthic invertebrates, especially gammarids, molluscs and insect larvae.

Conservation status. DD*.

Remarks. Diagnosis based on Ladoga population (true *C. widegreni*). Baltic populations (*C. "polonica"*) referred to this species are probably misidentified as they are shallow water, small-sized species (up to about 200 mm SL), while the true *C. widegreni* is a deep-water, large size species.

Further reading. Berg, 1948: 374 (morphology); Pravdin, 1954: 161, 175 (morphology, biology, distribution); Shaposhnikova, 1973 (Lake Ladoga; as valaamka); Svärdson, 1979: 8, 49, 85–86 (Baltic, Sweden).

British Isles

Six coregonid species are known from the British Isles. *C. vandesius* belongs to the *C. albula* species group (see below). *C. pollan* might as well belong to ciscoes, but is retained here until its relationships are better understood. *C. oxyrinchus* is recorded from England but is extinct since the late 19th century. It is included in the key but is discussed under North European species. *C. stigmaticus*, *C. clupeoides* and *C. pennantii* are usually called *C. lavaretus* in British literature (a species endemic to subalpine Lakes Bourget and Geneva France, Switzerland]). *C. stigmaticus*, *C. clupeoides* and *C. pennantii* each are endemic to one or few lakes.

Key to whitefishes in British Isles

1a – Mouth terminal. ..... *C. pollan*

1b – Mouth subterminal, lower jaw included in upper jaw. 2

2a – Snout pointed, about two times eye diameter; 36–44 gill rakers (anadromous). ..... *C. oxyrinchus*

2b – Snout less than two times eye diameter; 29–41 gill rakers (lacustrine). 3

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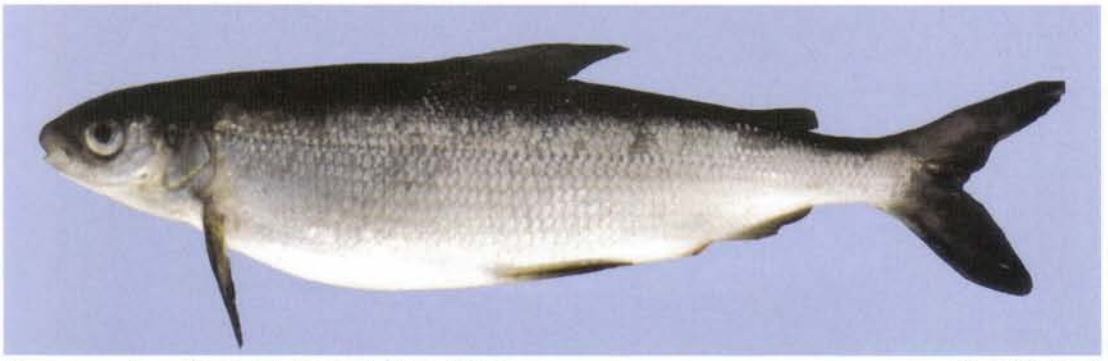


Coregonus clupeoides; Loch Lomond, Great Britain. P. S. Maitland

3a – Small blackish spots on back and flank; interorbital distance 3.0–3.3 times in H. ..... *C. stigmaticus*

3b – No small blackish spots on back and flank; interorbital distance 3.3–3.7 times in HL. 4

4a – 7½–8½ scale rows between lateral line and pelvic base; 20–21 circumpeduncular scale rows; 9–11½ branched anal rays. ..... *C. clupeoides*

4b – 8–10 scale rows between lateral line and pelvic base; 22–24 circumpeduncular scale rows; 11–13½ branched anal rays. ..... *C. pennantii*

Coregonus clupeoides

Common name. Powan.

Diagnosis. Distinguished from other species of *Coregonus* in British Isles by: ○ subterminal mouth, lower jaw included in upper jaw / ○ 29–39 gill rakers / ○ snout vertically truncate / ○ 9–11½ branched anal rays / ○ 7½–8½ scale rows between lateral line and pelvic base / ○ 20–21 circumpeduncular scale rows / ○ interorbital distance 3.3–3.4 times in HL. Size up to about 380 mm SL.

Distribution. Scotland: Loch Lomond and Loch Eck; introduced in two reservoirs in Loch Lomond basin (Loch Sloy, Carron Reservoir).

Habitat. Lacustrine, in open water.

Biology. In Loch Lomond, spawns in late December – early February, usually in early January, on offshore banks and reefs at temperatures close to 6°C. Feeds on crustaceans and insects.

Conservation status. VU D2*. Good stocks remain in natural range, two translocated stocks established in reservoirs.

Further reading. Regan, 1908b: 488, 1911: 121 (description); Sweetman et al., 1996: 25 (status); Kottelat, 1997: 120 (systematics); Maitland, 2004: 158 (distribution, biology).

Coregonus pennantii

Common name. Gwyniad.

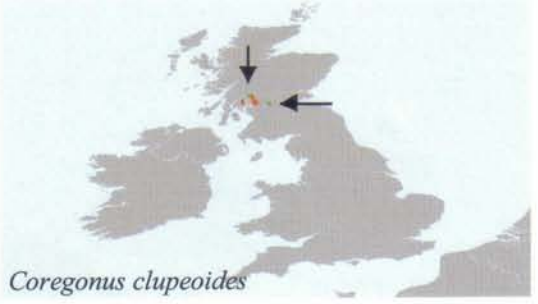
Diagnosis. Distinguished from other species of *Coregonus* in British Isles by: ○ subterminal mouth, lower jaw included in upper jaw / ○ snout vertically truncate / ○ 11–13½ branched anal rays / ● 8–10 scale rows between lateral line and pelvic base / ○ 22–24 circumpeduncular scale rows / ○ interorbital distance 3.3–3.7 times in HL / ○ 36–41 gill rakers. Size up to about 350 mm SL.

Distribution. Wales: Lake Llyn Tegid [Lake Bala].

Habitat. Lacustrine, in open water.

Biology. Spawns in January – February in shallow bays on stones and gravel. Feeds on crustaceans and insects.

Conservation status. CR B1ab(iii,v) + 2ab(iii,v); D2*. Threatened by degradation of water quality



Coregonus clupeoides

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Coregonus pennantii; Lake Llyn Tegid, Wales; ~200 mm SL. Countryside Council for Wales

and introduction of *Gymnocephalus cernua*, which preys on eggs and larvae. A second population is being established in Llyn Arenig.

Further reading. Regan, 1908b: 490, 1911: 124 (description); Kottelat, 1997: 121 (systematics); Maitland, 2004: 159 (distribution, biology; as *C. lavaretus*, in part).

Coregonus pollan

Common name. Pollan.

Diagnosis. Distinguished from other species of *Coregonus* in British Isles by: ● mouth terminal, lower jaw not projecting / ○ 41–48 gill rakers / ○ 74–92 total lateral line scales / ○ 7½–10 rows of scales between lateral line and pelvic origin. Size up to about 300 mm SL.

Distribution. Ireland: Lough Neagh, lower and upper Loughs Erne, Lough Ree and Lough Derg.

Habitat. Lacustrine, in open waters.

Biology. Lives up to 9 years. Spawns for the first time at 2 years. Spawns in October – December on rocky or gravel shallow areas. Feeds mainly on crustaceans (*Mysis relicta*), supplemented by insect larvae, shrimps and small fishes.

Conservation status. EN B1ab(iii) + B2ab(iii)*. Threatened by eutrophication, introductions and warming of lakes. Only remaining abundant population in Lough Neagh.

Further reading. Regan, 1908b: 485, 1911: 118 (description); Quigley & Flannery, 1996: 32 (status); Kottelat, 1997: 121 (systematics); Harrod et al., 2001 (conservation); Rosell et al., 2004 (conservation); Maitland, 2004: 157 (distribution, biology).

Coregonus stigmaticus

Common name. Schelly.

Diagnosis. Distinguished from other species of *Coregonus* in British Isles by: ● small blackish spots on back and flank / ○ subterminal mouth, lower jaw included in upper jaw / ○ snout vertically truncate / ○ 10–12½ branched anal rays / ○ 7½–8½ scale rows between lateral line and pelvic base / ○ 22–24 circumpeduncular scale rows / ○ interorbital distance 3.0–3.3 times in HL / ○ 34–41 gill rakers. Size up to about 320 mm SL.

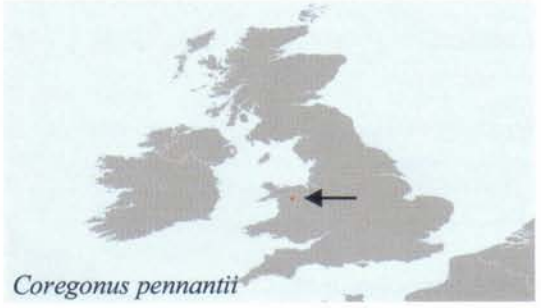
Distribution. England: Lakes Haweswater, Ullswaterand, Brotherswater and Red Tarn (Cumbria).

Habitat. Lacustrine, in open water.

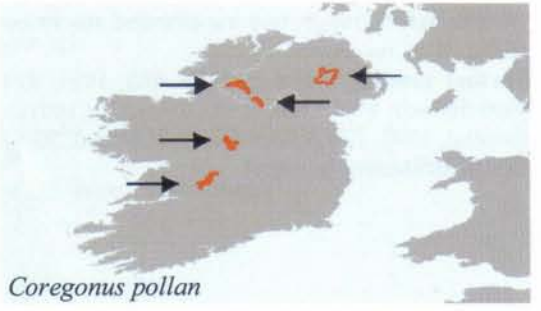
Biology. Spawns in January – February, in shallow bays on stones and gravel. Feeds on crustaceans and insects.

Conservation status. EN B2ab(ii,iii,v)*. Population in Haveswater strongly declined due to water abstraction and cormorant predation.

Further reading. Regan, 1908b: 489, 1911: 123 (description); Kottelat, 1997: 122 (systematics); Maitland, 2004: 158 (distribution, biology).



Coregonus pennantii



Coregonus pollan

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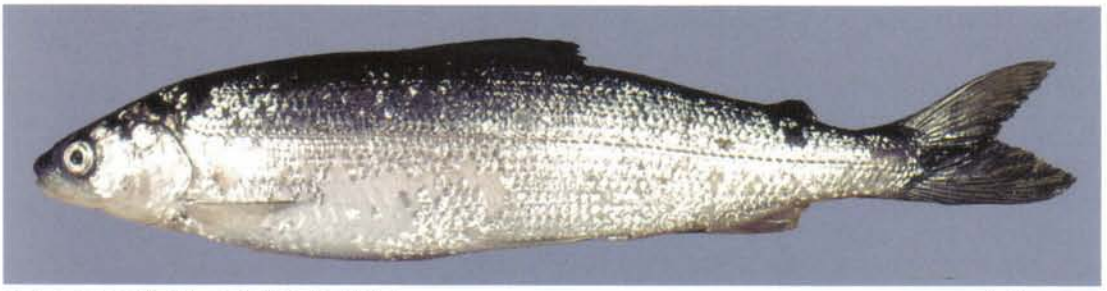
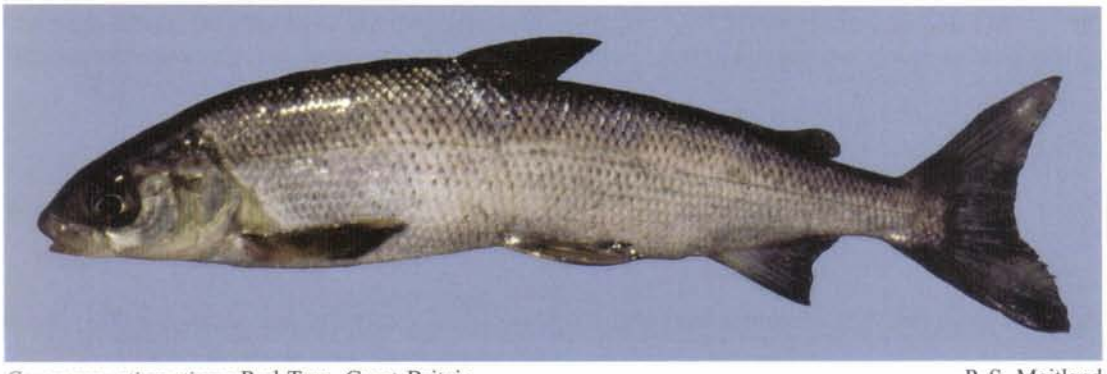


Coregonus pollan; Lough Neagh, Irland. A. Ferguson



Coregonus stigmaticus; Red Tarn, Great Britain. P. S. Maitland

Coregonus albula species group

Ciscoes or vendaces form a distinct natural group, which will probably have to be separated from *Coregonus* as a genus of its own. Some European species as *C. autumnalis*, *C. pollan* and *C. peled* might be more closely related to the *C. albula* group than to other coregonids. Until phylogenetic data allow a revision of the genus *Coregonus* (including *Stenodus*), we retain the *C. albula* group as a distinct unit within Coregonus. Ciscoes are usually semi-anadromous and this is the life-history they actually show in rivers of the Gulf of Finland, the White Sea and throughout Siberia. In Europe, however, most species and populations have a landlocked, lacustrine life-history.

There is an autumn spawning species in most lakes where ciscoes occur, but in several lakes, there are two species with distinct spawning seasons, one spawning in autumn and one spawning in winter or from spring to summer. Two such species pairs exist in northern Germany (lakes Breiter Luzin and Stechlin); the two spring-spawning species evolved independently and both are derived from the sympatric autumn spawning *C. albula*; they represent distinct evolutionary lineages, and thus are distinct species. The same has been suggested by allozyme data for Finish populations. Spring and late winter spawning ciscoes probably have also arisen from autumn spawning *C. albula* populations several times in parallel in Sweden and Russia and the species that we here call *C. trybomi* most likely is an artificial (polyphyletic) assemblage. Published data provide almost no characters to distinguish the different species outside the spawning season. This is not to say that the species do not differ morphologically but that there is no published morphological data.

Ciscoes from Lake Pletscheievo (former Pereslavkoye) might also be a distinct species. We were not able to examine material of this population.

Further reading. Schulz et al., 2006 (genetics, spring spawning).

Coregonus stigmaticus

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Key to *Coregonus albula* species group in Europe

Based on mature individuals.

1a – Spawns in autumn.
..... 2

1b – Spawns in late winter, spring or summer.
..... 6

2a – Eye diameter 29–32 % HL.
..... *C. vessicus*

2b – Eye diameter 21–28 % HL.
..... 3

3a – All fins dark grey to black posteriorly in individuals larger than 120 mm SL; usually reaching maturity at 150-200 mm SL; adults piscivorous.
..... 4

3b – All fins hyaline or pelvic and pectoral grey to black posteriorly in individuals larger than 150 mm SL; usually reaching maturity at 110-130 mm SL; adults planktivorous.
..... 5

4a – Lateral line bent anteriorly in most individuals; 43–55 (mode 50) gill rakers.
..... *C. ladogae*

4b – Lateral line straight; 41–46 (mode 43), rarely 38–48 gill rakers.
..... *C. kiletz*

5a – Head length 18–20 % SL.
..... *C. sardinella*

5b – Head length 20–25 % SL.
..... *C. albula*, *C. vandesius*

6a – Length of gill raker at angle of upper and lower limbs of first gill arch 100–120 % of opposite inner gill filament.
..... *C. trybomi*

6b – Length of gill raker at angle of upper and lower limbs of first gill arch 120–230 % of opposite inner gill filament.
..... 7

7a – 69–77 + 3 lateral line scales; head width between dorsal end of opercular openings 8.2–9.7 % SL (Lake Stechlin).
..... *C. fontanae*

7b – 72–82 + 3 lateral line scales; head width between dorsal end of opercular openings 7.1–8.3 % SL (Lake Breiter Luzin).
..... *C. lucinensis*

Coregonus albula

Common name. Baltic cisco.

Diagnosis. Distinguished from other species of ciscoes in Europe by: ● spawns in autumn and early winter / ● eye diameter 21-28 % HL / ● head length 20–25 % SL/ ● adults planktivorous. Size up to about 230 mm SL, but many populations much smaller.

Distribution. Baltic basin, lakes of upper Volga drainage (Seliger, Vseluga, Perejaslavskoe), some lakes of White Sea basin and North Sea basin east of Elbe drainage. Anadromous in Gulf of Finland and marine in northernmost freshened part of Gulf of Bothnia. North to about 69°N in Lake Inari, northern Finland. Lower Rhine (now extirpated). Frequently stocked in lakes and reservoirs in northern and central Germany and Poland.

Habitat. Lacustrine and marine in open water. At sea, forages close to coast. Spawns along shores, at 3–10 m depth, rarely to 22 m depth or just below surface. Spawns deeper in clear lakes and closer to surface in lakes with humic waters.

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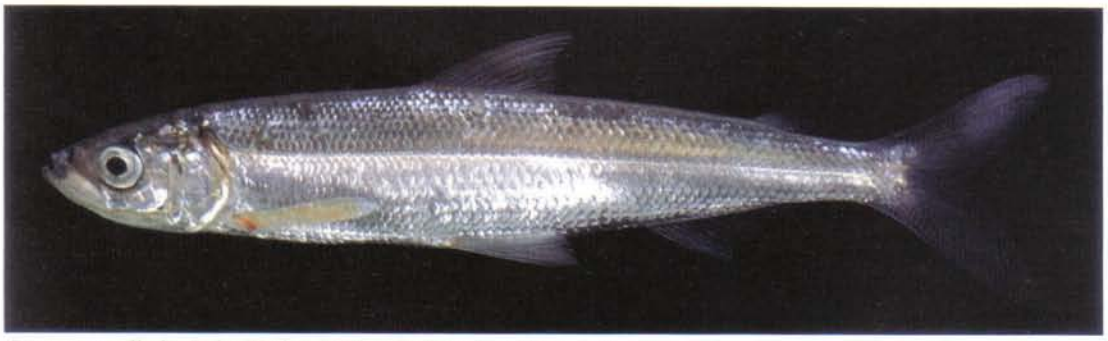
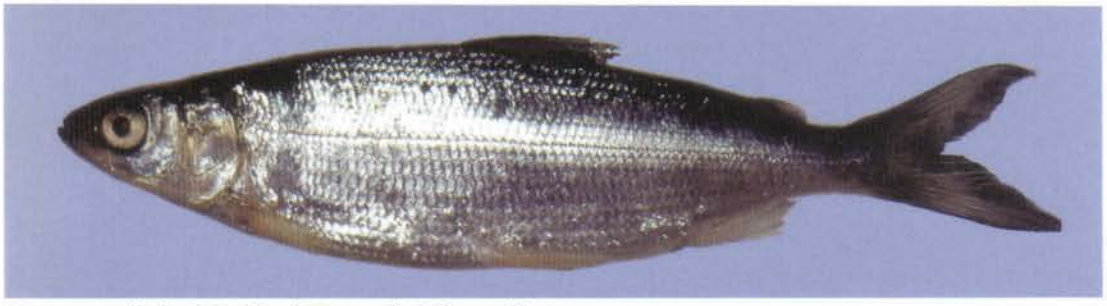


Coregonus albula; Lake Breiter Luzin, Germany; ~120 mm SL.



Coregonus albula; Lake Knud, Denmark; 160 mm SL.

Biology. Anadromous, marine and landlocked populations. Spawns for the first time at 2–5 years (2–3 in Lake Onega), males usually earlier than females. Spawns in October (central Finland), December (northern Germany) at 6–7°C. Anadromous populations start migrating to rivers in August (Neva). Eggs hatch in March – April and juveniles migrate to sea in late summer of first year in anadromous populations. Larvae pelagic close to surface, usually close to shore. Adults, usually in deep waters in daytime, move to upper layers at night. Feeds on zooplankton.

Conservation status. LC*, but identities of most lacustrine populations need to be confirmed; several species are possibly confused under the name *C. albula*.

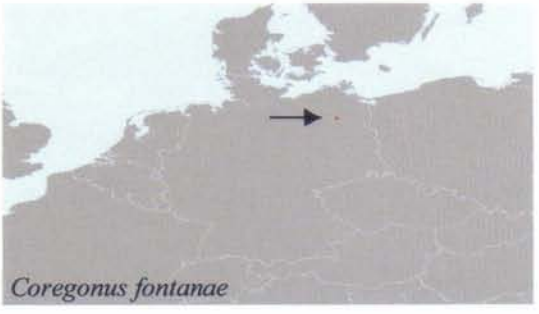
Remarks. Available data do not allow to distinguish *C. albula* as a whole from *C. sardinella* and *C. vandesius*, but individual populations are diagnosably distinct from these two species. A very high variability is reported for all morphological characters between the many populations referred to *C. albula*, suggesting that several species might be involved. Further studies are needed to resolve their identity.

Further reading. Svärdson, 1979: 87–88 (morphology, distribution); Nikolski & Reshetnikov, 1970: 253 (systematics).

Coregonus fontanae

Common name. Stechlin cisco.

Diagnosis. Distinguished from sympatric *C. albula* in Lake Stechlin and geographically close *C. lucinensis* by: ○ 69–77 + 3 lateral line scales (vs. 76–88 + 3 in sympatric *C. albula*; 72–82 + 3 in *C. lucinensis*) / ○ interorbital distance 25–30 % of dorsal HL (vs. 30–38 in sympatric *C. albula*) / ○ head width between dorsal end of opercular openings 8.2–9.7 % SL (vs. 7.1–8.3 in *C. lucinensis*) / ○ length of gill raker at angle of upper and



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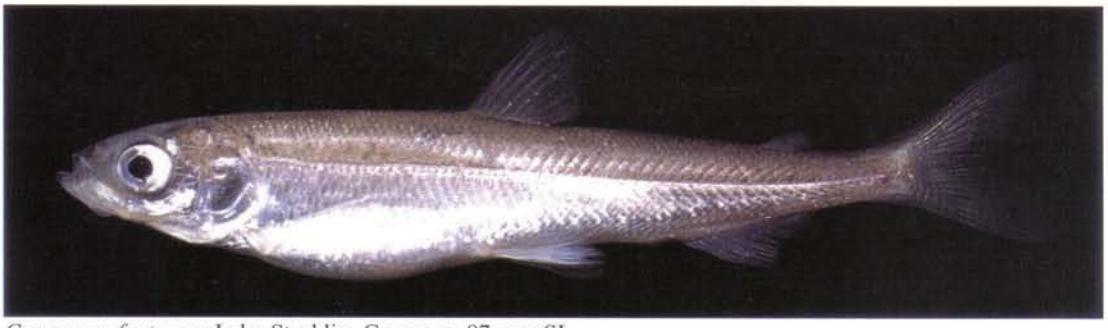
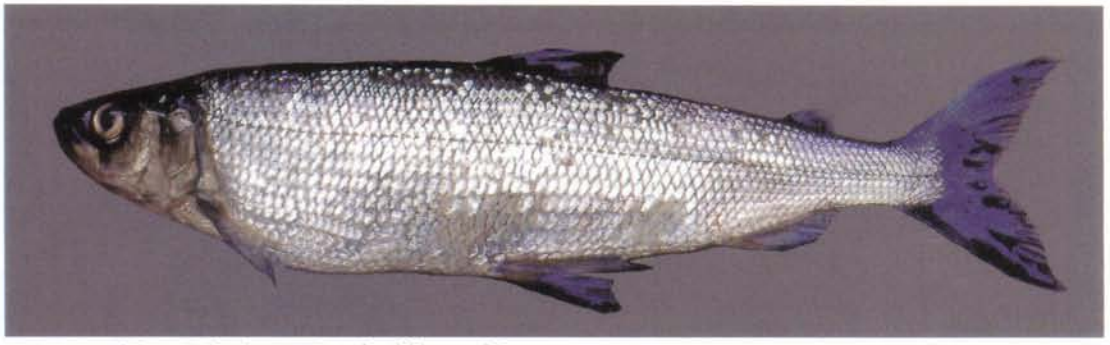


Coregonus fontanae; Lake Stechlin, Germany; 87 mm SL.



Coregonus kiletz; Lake Onega, Russia; 300 mm SL.

lower limbs of first gill arch 120–186 % of opposite inner gill filament (vs. 92–148 in sympatric *C. albula*), 11–18 % of dorsal HL (vs. 18–24 in sympatric *C. albula*) / ○ slow growth, females mature at 90–126 mm SL (vs. fast growth, 136–167 in sympatric *C. albula*; 123–162 in *C. lucinensis*) / ○ spawns in spring and early summer. Size up to 126 mm SL.

Distribution. Northern Germany: Lake Stechlin.

Habitat. Lacustrine, inhabits deep water layers (20–60 m), migrates above 20 m at night. Lake Stechlin is a 4.25 km^2 oligotrophic lake (mean depth 23 m, maximum depth 69 m) formed during Weichselian glaciation (about 12,000 years BP).

Biology. Spawns for the first time at 2 years, 65–110 mm SL for females. Spawns in April – September, usually May – June. Most individuals spawn only for a single season. Feeds mainly on Cladocera and Copepoda.

Conservation status. LC*. A single known population. Abundant in Lake Stechlin, no commercial value due to small size.

Further reading. Schulz & Freyhof, 2003: 212 (description).

Coregonus kiletz

Coregonus kiletz

Common name. Kiletz.

Diagnosis. Distinguished from other species of ciscoes in Europe by: ● head and body dark grey to black with violet iridescences in life and shortly after death / ○ eye diameter 22-27 % HL / ○ lateral line straight / ○ 41-46 (mode 43) gill rakers / ○ adults piscivourous / ○ spawns in late October – early November. In Lake Onega, distinguished from sympatric *C. albula* by: all fins dark grey to black (vs. hyaline) / eggs dark yellowish pink (vs. pale yellow) / usually reaching maturity at 200 mm SL (vs. 90-120 mm). Size up to 390 mm SL.

Distribution. Russia: Lake Onega.

Habitat. Lacustrine, at all depths.

Biology. Lives 7–9 years, exceptional records up to 19 years. Spawns for the first time at 4–6 years. Spawns in late October – early November at 2–5°C. Sympatric *C. albula* spawns in late October, at 3–7°C. Juveniles feed on zooplankton and small benthos. Switches to a fish diet (mostly *Osmerus eperlanus*) at 170–200 mm SL.

Conservation status. LC*.

Further reading. Babii & Sergeeva, 2003 (biology; as *C. albula*).

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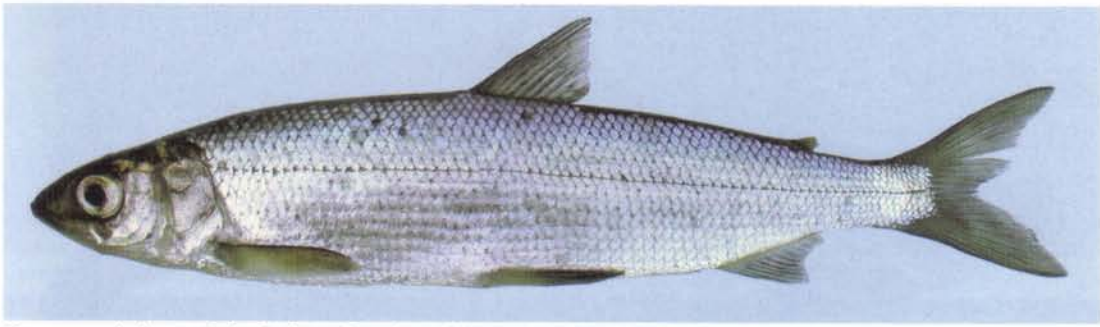

Coregonus ladogae; Lake Ladoga, Russia; ~200 mm SL (individual with straight lateral line). A. Naseka

Coregonus lucinensis; Lake Breiter Luzin, Germany; ~120 mm SL.

Coregonus ladogae

Common name. Ripus.

Diagnosis. Distinguished from other species of ciscoes in Europe by: ● lateral line bent anteriorly in most individuals / ○ spawns in late October – early December / ○ eye diameter 23-28 % HL / ○ adults piscivorous. In Lake Ladoga, distinguished from sympatric *C.* cf. *albula* by: black pectoral and pelvic (vs. hyaline) / green-black back (vs. dark blue or violet) / pectoral reaching beyond halfway between pectoral and pelvic bases (vs. not reaching) / 43–55 (mode 50) gill rakers (vs. 34–45, mode 38) / eye diameter 23–28 % HL (vs. 28–34) / usually reaching maturity at 2 years, 150 mm SL, 50–60 g (vs. 1 year, 70–85 mm SL, 6–8 g). Size up to 430 mm SL.

Distribution. Lake Ladoga. Widely introduced to lakes in Latvia, European Russia and Siberia.

Habitat. Lacustrine.

Biology. Spawns for the first time at 2 years and 30 g (males) and 60–70 g (females). Spawns in early winter. Juveniles feed on zooplankton, adults on fish (mostly *Osmerus eperlanus*). Reported to hybridise with other *Coregonus* species.

Conservation status. LC*. Widely translocated in Russia.

Further reading. Pravdin et al., 1938 (description; as *C. albula* infrasp. *ladogae*); Berg, 1948: 323 (description; as *C. albula* infraspecies *ladogensis*); Kottelat et al., 2005: 184 (nomenclature).

Coregonus lucinensis

Common name. Quietschbüker.

Diagnosis. Distinguished from sympatric *C. albula* in Lake Breiter Luzin by: ● length of gill raker at angle of upper and lower limbs of first gill arch 130–230 % of opposite inner gill filament (vs. 90–134), 13–19 % of dorsal HL (vs. 18–26) / ● depth of caudal peduncle 1.9–2.2 times in its length (vs. 1.4–1.9, rarely up to 2.1). Distin-

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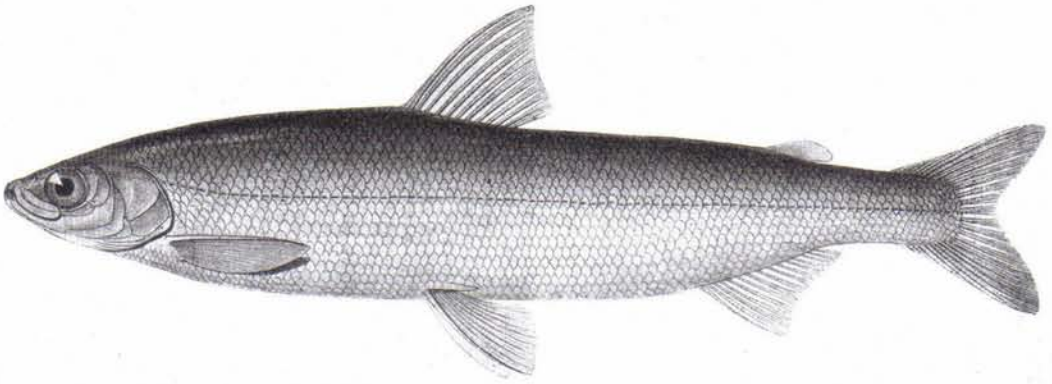


Coregonus sardinella; Lena, Russia; 301 mm SL. (from Borisov, in Berg, 1932)

guished from geographically close *C. fontanae* by: ● 72–82 + 3 scales in lateral line (vs. 69–77 + 3) / ● head width between dorsal end of opercular openings 7.1–8.3 % SL (vs. 8.2–9.7). Size up to 160 mm SL.

Distribution. Northern Germany: Lake Breiter Luzin.

Habitat. Lacustrine, reported to inhabit deep water layers (20–58 m) and move to shallow waters to spawn. Lake Breiter Luzin is a 3.45 km^2 mesotrophic lake (formerly oligotrophic), maximum depth 58 m.

Biology. Lives up to 6 years. Matures at 2 years. Spawns in April – July, usually May – June. Feeds mainly on chironomids and *Mysis relicta*.

Conservation status. VU D2; a single known population, strongly declined due to euthrophication, but now recovering with improved water quality.

Further reading. Thienemann, 1933: 655 (description); Kottelat, 1997: 120 (systematics); Waterstraat, 1990 (morphology, ecology).

Coregonus sardinella

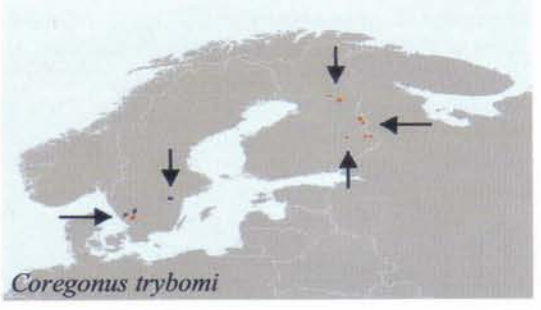
Common name. Siberian cisco.

Diagnosis. Distinguished from other species of ciscoes in Europe by: ○ spawns in autumn and early winter / ● head length 18–20 % SL. Size up to about 350 mm SL.

Distribution. Lakes and lower course of large rivers of Arctic Ocean basin, from Pechora drainage to eastern Siberia; North America eastward to Bathurst (Canada). *C. 'albula'* from Lakes Mjosa and Osensjoen (Norway) might also belong to this species.

Habitat. Lakes, estuaries and large rivers. Semi-anadromous populations forage in estuaries, lower courses of rivers, backwaters and lakes. Spawns on sand and gravel, in deep pools.

Biology. Lacustrine and semi-anadromous populations. Lives up to 10 years, exceptional records up to 22 years in Norway. Spawns for the first time at 3–4 years. Semi-anadromous populations migrate upstream in June – September; in Pechora up to 800–1000 km from sea. In Kara, spawns in estuary. In Kara and some Siberian rivers, two spawning runs are known. First run enters rivers in August and spawns in September; second run starts in September and spawns in October soon before or after appearance of ice. Eggs hatch in spring and juveniles remain near spawning site until first autumn, then move downriver. In tundra lakes, spawns under first ice in October. Feeds on zooplankton, crustaceans and small fish. Adults do not feed during spawning migration. An isolated, dwarf population growing to about 100 mm



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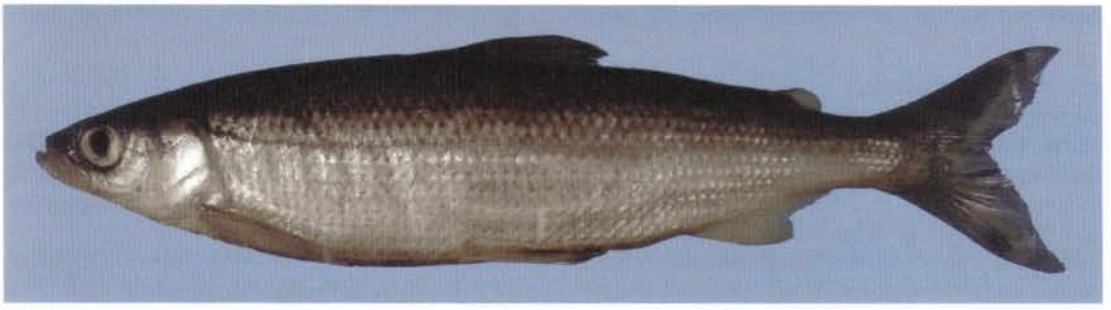
Coregonus trybomi; Lake Ören, Sweden; 190 mm SL.



Coregonus vandesius; Lake Derwentwater, England; 190 mm SL.

SL is known from Vashutkiny lakes, in upper Usa drainage, a Pechora tributary. The Pechora population may at least partly result of hybridisation between *C. albula* and *C. sardinella*.

Conservation status. LC.

Remarks. See Remarks under *C. albula*.

Further reading. Nikolski & Reshetnikov, 1970: 253 (systematics); Solovkina, 1974 (biology); Svärdson, 1979: 87–88 (diversity); Sendek, 2002 (Pechora).

Coregonus trybomi

Common name. Spring spawning cisco.

Diagnosis. Distinguished from other species of ciscoes in Europe by: ♦ predorsal length 47–50 % SL / ♦ length of gill raker at angle of upper and lower limbs of first gill arch 100–120 % of opposite inner gill filament / ♦ spawns in spring and early summer. Size up to about 200 mm SL. Reportedly, there is no external characters distinguishing this species from sympatric autumn spawning *C. albula*.

Distribution. Sweden: Lakes Ören (Motalaström drainage), Hålsjön (Viskan drainage), Äsunden, Fegen (Ätran drainage).

Habitat. Lacustrine, deep water.

Biology. Spawns in late April – early May (Sweden), at 10–30 m depth. In all lakes, spring spawning *C. trybomi* occur in sympatry with *C. albula*. Feeds on plankton. In October – November rises to surface, probably to feed on spawn of *C. albula*.

Conservation status. CR B1ab(iii,iv) + 2ab (iii,iv)*, a single known population remains in Sweden. Vanished from Lakes Ören, Hålsjön and Äsunden because of acidification (acid rain) and stocking of alien species. No actual information available for Finnish and Russian populations (assuming they are conspecific).

Remarks. Similar *Coregonus* are known from Lakes Änättijärvi, Kostonjärvi, Kokkamo, Pirttijärvi, Suomunjärvi (winter spawning), Sokojärvi, Kajoonjärvi, Luovijärvi, Siikajärvi (spring spawning) in Finland and some lakes of Karelia (winter spawning; e.g. Korpiselkä), and probably others in Russia. In all lakes they are in sympatry with *C. albula*. They had been referred to as *C. trybomi*. Allozyme data suggest that the different populations have arisen independently from a sympatric population of autumn spawning ciscoes and are distinct species. In this case, three of the four species endemic to Sweden are already extinct. We were not given access to the material that would have allowed to clarify the taxonomy of these populations.

Further reading. Airaksinen, 1968 (biology, Finland); Svärdson, 1979: 71 (description); Vuorinen et al., 1981 (genetics).

Coregonus vandesius

Common name. Vendace.

Diagnosis. Distinguished from other ciscoes in Europe by: ♦ spawns in November – December / ♦ eye diameter 24-28 % HL / ♦ head length 20–23 % SL / ♦ pectoral and pelvic hyaline with dark grey tip in adults / ♦ adults planktivorous. Size up to about 200 mm SL.

Distribution. England: Lakes Derwentwater and Bassenthwaite (Cumbria); Scotland: Castle Loch and Mill Loch near Lochmaben.

Habitat. Lacustrine, in open water. Spawns on

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Coregonus vessicus; Lake Beloye, Russia; 120 mm SL.

gravel or stone shores.

Biology. Gregarious, shoaling. Lives up to 10 years. Spawns for the first time at 2–3 years. Spawns in November – December. Males gather in spawning places and females join these shoals and spawn together in midwater. Eggs sink to bottom and develop between stones. Shoals move to deeper water in warm weather. Comes closer to shores in late summer. Feeds mainly on crustaceans (*Entomostraca*), supplemented by small insects.

Conservation status. EN B1ab(iii) + 2ab(iii)*. Low population abundance and inconsistent recruitment in Bassenthwaite. Extirpated in Castle Loch and Mill Loch due to eutrophication. Last safe native population in Derwentwater. Translocated population established in Loch Skene [from Bassenthwaite Lake].

Remarks. The populations of Cumbria and Scotland differ somewhat in morphology and might be distinct species. On the other hand, available data do not allow to distinguish *C. vandesius* from the assemblage of all populations referred to *C. albula* and *C. sardinella*. See Remarks under *C. albula*. However, *C. vandesius* is clearly distinct from *C. albula* populations from eastern Baltic basin, but it is similar to some populations from the western Baltic.

Further reading. Regan, 1908b: 484, 1911: 113 (description); Winfield et al., 1996 (ecology), 2004 (conservation); Kottelat, 1997: 122 (systematics); Maitland, 2004: 156 (distribution, biology, conservation).

Coregonus vessicus

Common name. Beloye cisco.

Diagnosis. Distinguished from other ciscoes in Europe by: ○ spawns in November / ● eye diameter 28–33 % HL / ○ pectoral and pelvic hyaline in adults / ○ adults planktivorous. Size up to 200 mm SL.

Distribution. Russia: native in Lake Beloye [Belozero], northern Volga drainage (60°11'N 37°34'E). Invasive in upper and middle Volga reservoirs downriver to Saratov reservoir.

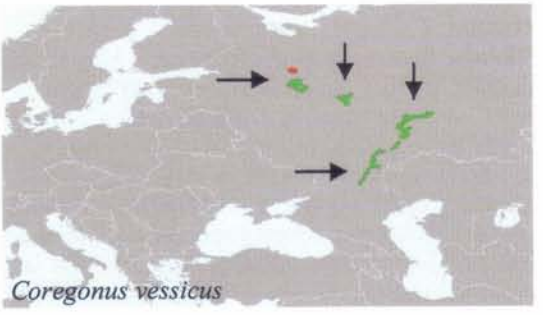
Habitat. Lacustrine.

Biology. Lives up to 2½ years. Spawns for the first time at 2 years, males may spawn for the first time in their first year. Spawns usually around 10 November. Most individuals spawn only for a single season.

Conservation status. LC*. Abundant in Lake Beloye. Invasive and spreading in Volga drainage.

Further reading. Berg, 1948: 333 (description).

Coregonus vandesius



Coregonus vessicus

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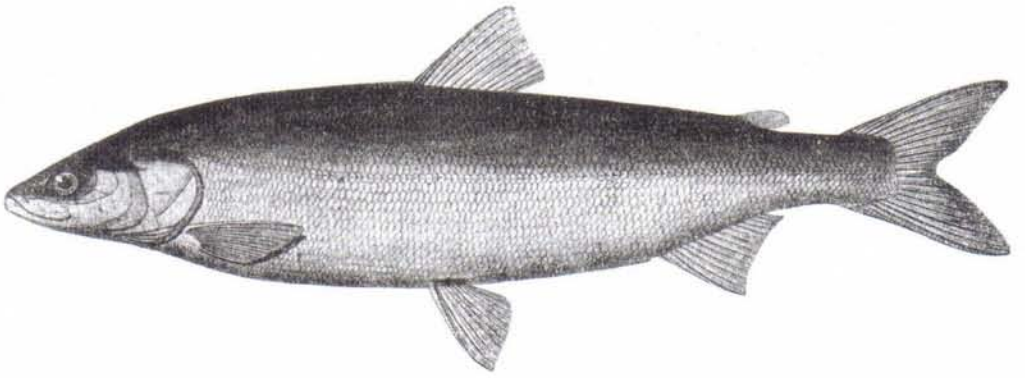


Stenodus leucichthys; coast of Caspian Sea, Russia; 450 mm SL. (from Berg, 1932)

Stenodus

Stenodus are large, piscivorous coregonids known from the Volga drainage and arctic and subarctic rivers and lakes. Although morphologically very distinctive, molecular data suggest that, under contemporary systematic concepts, *Stenodus* probably is only a lineage within *Coregonus*. We recognize two species in *Stenodus*. *S. leucichthys* is at the very brink of extinction, totally depending on stocking. The increased connectivity of water bodies in northeastern Europe allowed *S. nelma* to enter lakes connected to the upper Volga basin, where it could be an additional threat to *S. leucichthys*.

Stenodus leucichthys

Common name. Belorybitsa.

Diagnosis. Distinguished from *S. nelma* by: ● head width 30–40 % HL / ● interorbital distance 20–26 % HL. Size up to 1300 mm SL.

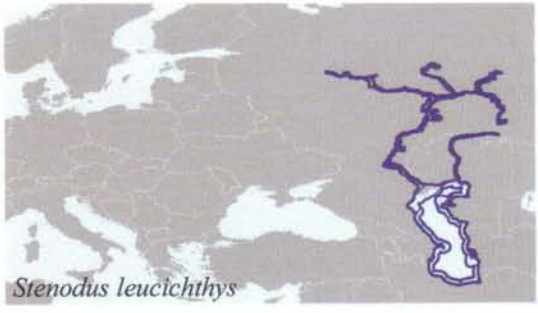
Distribution. Caspian Sea (commonly central and southern Caspian in summer), Volga, Ural and Terek drainages.

Habitat. At sea, throughout basin in pelagic zone with temperatures below 18°C and 20–50 m deep. Juveniles and adults overwinter and forage at sea. Large lowland rivers during migration. Prior to the construction of dams, migration route was over 3000 km long, reaching up to uppermost reaches of Ufa and Belaya drainages (Kama tributaries). Spawns on gravel shallows.

Biology. Anadromous. Spawns for the first time at 5–8 years, females usually 2 years later than males. In autumn, starts migration from sea to estuaries. Mature adults enter Volga, only few individuals enter Terek and Ural. Migration takes almost a year. Spawns in September – October at temperatures below 6°C. Adults migrate back to sea soon after spawning, but many die. Eggs adhere to gravel and rocks. Embryonic development lasts about 6 months, alevins appear in April. Fry actively migrates to sea soon after start of exogenous feeding. At 30 days, juveniles already start to feed on fry of other fishes. Adults feed exclusively on fish. Active predator, feeds on all available fish, commonly small schooling species.

Conservation status. EW. Due to loss of all spawning grounds, native stocks are reportedly extinct and survival depends exclusively on stocking. In Volga all spawning grounds were above Volgograd dam. In 1959 only a few spawners remained. Up to 33 million (1988) juveniles were stocked during Soviet times. Between 1996–99 only 600,000 juveniles were stocked and the spawning population is in a drastic decline again. In 2004, only about 100 spawners were recorded below Volgograd dam. Increasing illegal fishing in the Volga and in the Caspian Sea is now a very critical concern. *S. nelma* introduced in northern Volga drainage is now expanding its range and might threaten possibly surviving populations and cultivated stocks by hybridisation. In the 1960s, it was already extremely rare in the Ural, where it has not been recorded since.

Further reading. Shaposhnikova, 1967: 225 (morphology, taxonomy); Reshetnikov, 1980: 210 (morphology, distribution); Belyaeva et al., 1989 (biology, fisheries).



Stenodus leucichthys

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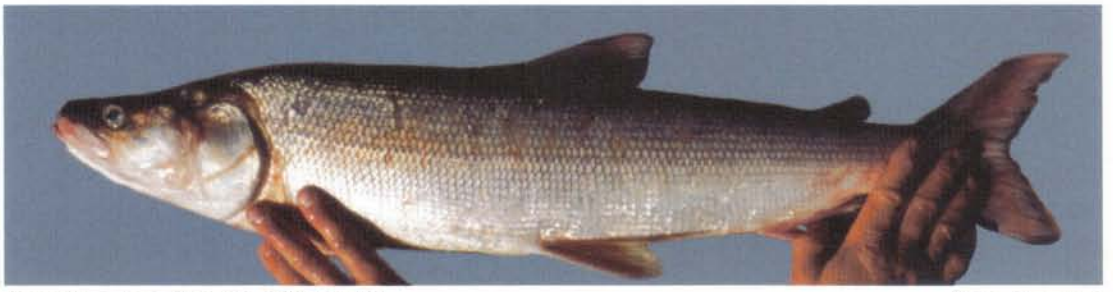

Stenodus nelma; Canada; ~700 mm SL. K. L. Howland

Stenodus nelma

Common names. Nelma (Russia), inconnu (North America).

Diagnosis. Distinguished from *S. leucichthys* by: ● head width 27–30 % HL / ● interorbital distance 15–22 % HL. Size up to 1500 mm SL.

Distribution. Arctic Ocean basin, from Ponoi (Kola Peninsula, White Sea basin) eastward to Anadyr (Siberia), Yukon (Alaska) and Mackenzie (Canada) drainages.

Habitat. At sea, in pelagic zone with water salinity up to 20‰. Large lowland and piedmont rivers and lakes. Prefers cold water with temperatures below 16°C. Forages and overwinters in lower reaches of large rivers, deltas, estuaries and sea, sometimes rather far from coast. Migrates for spawning in rivers, moving upstream for long distances, up to uppermost reaches in European rivers. Lacustrine populations migrates into tributaries. Spawns over shallows with sand-gravel bottom and 2–3 m depth.

Biology. Anadromous or semi-anadromous, resident in some rivers and landlocked in some lakes. Resident and anadromous individuals co-occur in some rivers in North America. Anadromous populations spawn for the first time at 600–900 mm SL and 8–16 years, females 2–3 years later than males. Freshwater populations may mature earlier, males at 4, females at 5 years and have shorter life cycle. Usually spawns only 1–2 times during life, rarely 3, usually every 2–3 years. Starts migration in early spring just after ice melting, reaches spawning sites by autumn. Spawns in September – October, 80,000–420,000 non-sticky eggs. Adults actively feed after spawning and spend following winter and spring in river, return to lower reaches and sea by next summer. Embryonic development lasts 250–260 days, larvae (12–14 mm) appear in May – June. Fry migrates to sea soon after start of active feeding or remain 2–3 years in rivers. Juveniles feed on mysids, insect larvae and fry, become exclusively piscivorous at about 300 mm SL. Active predator feeding on all available fishes. Occasionally hybridises with *Coregonus* species.

Conservation status. LC. Stocks in European and Siberian rivers declining.

Further reading. Shaposhnikova, 1967: 225 (morphology, taxonomy); Reshetnikov, 1980: 210 (morphology, distribution); Danilov-Danilyan, 2001: 284 (conservation).

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Family Salmonidae

Salmons, trouts, charrs

Salmonids are medium to large size fishes inhabiting almost all habitats with clear, cold and well oxygenated water. Salmonids are native to the northern hemisphere, but have been widely introduced for aquaculture, commercial and recreational fisheries in cold waters all around the world. They have a very diverse and fascinating evolutionary biology, grow to a commercial size, have a good tasting flesh with few bones and are spread almost throughout Europe. Nevertheless, few groups of fishes have been so heavily impacted by human activities. The most important problems for salmonid conservation is the stocking of alien salmonid species or populations for recreational and commercial purposes. Salmonid stocking resulted in a genetic pollution of many native populations. Our knowledge of the extend of this problem is still very poor. It is hard to guess how many native trout and charr populations have been lost due to hybridisation with "nicer", "better growing" or "tastier" fishes. This was studied in detail in a single species, in a small part of its range. The Adriatic *Salmo marmoratus* is heavily polluted and only very few genetically 'original' populations remain, despite its large distribution range. These observations certainly apply to a great number of species and populations. Identification of salmonid genera is often based on internal characters such as the shape and dentition of the vomer (a bone on the roof of the mouth; Fig. 71) or on the number of pyloric caeca (appendices located on the anterior area of the stomach). We tried to avoid the use of these characters for identification as their examination results in damaging the specimen.

Further reading. Stearley & Smith, 1993 (systematics); Hendry & Stearns, 2004 (evolutionary biology).

Key to genera of Salmonidae in Europe

1a – Lateral line scales very elliptical, reduced to little more than nerve tube (Fig. 72a-b), smaller than scales in adjacent rows, with no or little overlap with scales in front or behind. 2

1b – Lateral line scales roughly circular (Fig. 72c), as large as or larger than scales in adjacent rows, overlapping with scales in front and behind. 4

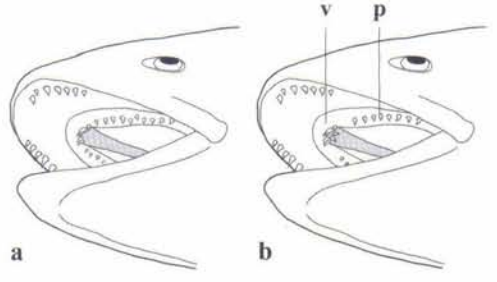

Figure 71 Vomerine teeth of Salmonidae showing position of vomer (gray). **a,** vomerine (**v**) and palatine (**p**) teeth forming a continuous horse-shoe shaped band; **b,** vomerine and palatine teeth separated.

Figure 72 Lateral line scales of Salmonidae, dorsal view. **a-b,** reduced to nerve tube (**a,** *Salvelinus fontinalis*; **b,** *Hucho hucho*); **c,** not reduced, roughly circular (*Salmo trutta*) (after Holčík et al., 1988).

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2a – Lateral line scales 100–120; lips fleshy; jaw teeth small or indistinct; 26–32 gill rakers; snout blunt; mouth subinferior (Adriatic basin in Croatia, Bosnia-Herzegovina and Montenegro). ..... *Salmo obtusirostris*

2b – Total lateral line scales 180–290; lips not fleshy; jaw teeth conspicuous; 9–34 gill rakers; snout pointed, rounded or blunt; mouth terminal (subinferior in some lacustrine species). 3

3a – Pale spots on body (red in *S. fontinalis*); vomerine and palatine teeth separated (Fig. 71b); anal and pelvic often with white anterior margin; 9–19 gill rakers; size up to 800 mm SL, in most species less than 400 mm SL. ..... *Salvelinus*

3b – Black spots on body; vomerine and palatine teeth forming a continuous horse-shoe shaped band (Fig. 71a); anal and pelvic never with white anterior margin; 18–34 gill rakers; size up to 1500 mm SL. ..... *Hucho*

4a – Caudal with black spots at least on upper lobe, usually on whole fin; flank with a pinkish to red midlateral stripe or band, at least in spawning season; no or few small black spots on opercle; usually 9–15½ branched anal rays (except *O. mykiss*, 6–9½ rays). ..... *Oncorhynchus*

4b – Caudal plain; flank without red midlateral stripe or band; several or large black spots on opercle; 6–9½ branched anal rays. ..... *Salmo*

Hucho hucho

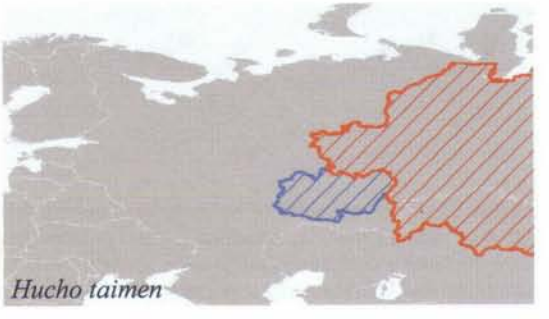
Common name. Huchen.

Diagnosis. Distinguished from other central and eastern European Salmonidae by: ○ 180–200 scales along lateral line / ○ absence of red spots and white fin margins / ○ head long (22–24 % SL) and dorsally flattened / ○ body roundish / ○ caudal deeply emarginate / ○ large size (in undisturbed areas) / ○ usually 13–19 gill rakers. See *H. taimen* for characters distinguishing the two species. Largest documented size 1650 mm SL and 60 kg, might reach up to 1800 mm SL.

Distribution. Danube drainage. Very locally introduced in some headwaters of Odra, Vistula (Poland), Lake Constance (Germany), Tagus (Spain), Rhône (France) and probably other drainages where it apparently maintains only by stocking.

Habitat. Montane and submontane reaches of large streams and swift rivers with gravel beds, well oxygenated, fast-flowing water and temperatures rarely above 15°C. Prefers deep pools and shady water under overhanging vegetation. Spawns in very clean gravel in fast-flowing water, usually in small river tributaries.

Biology. Lives more than 20 years. Males reproduce for the first time at 3–4 years and about 1 kg, females at 4–5 years and 2–3 kg. Spawns every year in early spring, usually March – April, rarely early May, when temperatures reach 6–10°C. Commonly migrates upriver for spawning in upper reaches of tributaries. Males arrive first at spawning sites. Males guard females against other males. Both sexes excavate a redd about 1.2–3.0 m in diameter, 10–20 cm deep, and defend a small territory in spawning grounds against other individuals. Usually spawns during daytime. During spawning act, both sexes cover the eggs with substrate. Both sexes may defend the spawning site up to 2 weeks after spawning. Eggs usually hatch after 25–40 days. Larvae remain in gravel until yolk sack is absorbed after 8–14 days. Juveniles inhabit fast-flowing waters and feed on drift-



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Hucho hucho; Danube drainage, Germany; juvenile, ~100 mm SL. A. Hartl

Hucho hucho; Danube drainage, Germany; nuptial male, ~700 mm SL. A. Hartl

ing invertebrates, becoming piscivorous after 1–3 years. Adults feed on fishes as well as small terrestrial vertebrates. Juveniles and adults are territorial.

Conservation status. EN B2ab(ii,iii). Most populations exclusively depend on stocking; natural reproduction very limited due to habitat alterations.

Further reading. Harsanyi, 1982 (biology); Holčík et al., 1988 (biology).

Hucho taimen

Common name. Taimen.

Diagnosis. Distinguished from other central and eastern European Salmonidae by: O teeth on vomer and palatine in a continuous, horse-shoe-shaped band / O 173–288 scales in midlateral row (107–164 pored scales) / O small round dark spots on head and dark x-shaped or/and half-moon-shaped spots on body / O head long (22–25 % SL) and dorsally flattened / O very long jaws, maxilla length 42–50 % HL; in adults, maxilla reaching posterior margin of eye / O shallow cylindrical

Salmonid jargon

Considering their popularity among sport fishermen, their economic and gastronomic value, and the number of people working on Salmonidae, it is not surprising that a very specialised vocabulary has evolved or that some common words take special meanings when applied to them. A few examples:

alevin: hatched fish with yolk-sack.

fry: fish emerging from spawning site and starting to feed.

kelt: post-spawning fish.

kype: upward curved hook at tip of lower jaw of sexually mature males.

parr: juvenile fish after complete absorption of yolk sack and before smoltification, usually with colour pattern consisting of a midlateral series of dark blotches.

parr marks: midlateral series of dark blotches on young salmonids, usually absent in adult.

pre-smolt: stage intermediate between parr and smolt.

redd: gravel nest.

smolt: fish ready to migrate to sea or when migrating, more elongate than pre-smolts and with silvery colour; smolt stage end when entering the sea.

whitling: juvenile during marine phase.

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Hucho taimen; Onon drainage, Mongolia; juvenile, 118 mm SL.

Hucho taimen; Selenge, Yenisei drainage, Mongolia; ~1200 mm SL. Z. Hogan

body / ○ caudal deeply emarginate, reddish in adults / ○ large size (in undisturbed areas) / ○ 9–18 (usually 11–13) gill rakers.

Distinguished from *H. hucho* by: ○ fewer gill rakers (usually 11–13, vs. 13–19) / ● outside spawning season, body and head olive brown, belly and caudal carmine or raspberry red (vs. body and head yellowish brown or brownish red, flank with yellowish to orangeish red iridescence, belly yellow) / ● in spawning season, body and anal and caudal carmine red, head and dorsal olive brown (vs. bright brownish red, anal and caudal without bright red coloration). Size up to at least 2000 mm SL and 105 kg, in Europe up to about 1500 mm and 40 kg.

Distribution. Arctic Ocean basin: in Siberia from Ob' to Yana drainages; Pacific Ocean basin: Amur and some adjacent drainages; in Europe, some upper tributaries of Pechora, and Kama (with tributaries Vyatka, Belaya, Vishera, Chusovaya) in Volga drainage. Prior to the impoundment of Kama, used to enter Volga and to reach downriver to Samara.

Habitat. Piedmont and montane cold rivers with high oxygen concentrations. Prefers deeper holes with slow current for periods of reduced activity (day time, winter), but also lower reaches, estuaries, cold lakes and reservoirs. Immature individuals have no permanent territory. Adults often stay within their own restricted territory (deep holes below rapids and waterfalls, confluence of small tributaries, below bridge pillar or large rocks, bank excavations), which they leave only for foraging and spawning. Spawns in shallow places with fast current on pebble bottom, immediately downstream of large deep pools. often in small river tributaries.

Biology. Lives up to about 20 years. Males reproduce for the first time at 4–7 years (northern populations later than southern ones) and about 1 kg, females at 5–8 years and 2–3 kg. Females in northern populations probably do not spawn every year. Spawns in early spring, usually in May, when temperatures reach 5–10°C. Commonly migrates upriver for spawning in upper reaches of tributaries. Able to overcome quite high obstacles while migrating to spawning grounds. Female excavates a redd about 1.0–1.5 m in diameter. Eggs are 5–6 mm in diameter and hatch after 28–38 days. Alevins remain in gravel until yolk sack is absorbed after 10–15 days. Young first stay near spawning site, then move downstream. Larger immature individuals 2–4 years old inhabit same sites as adults but separately below groups of adults or in smaller holes. Juveniles inhabit fast-flowing waters and feed on drifting invertebrates and become piscivorous after 1–3 years. Feeds on fishes as well as small terrestrial vertebrates. Juveniles and adults are territorial.

Conservation status. LC*, critically threatened in European Russia, almost extirpated in Pechora drainage. Sharply decreased in part of its Asian range due to pollution and overfishing, including by the recent development of angling tourism.

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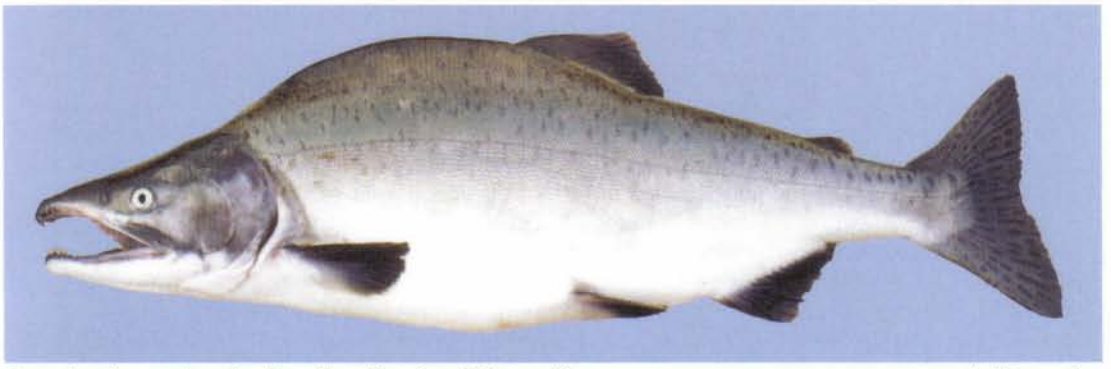

Oncorhynchus gorbuscha; Kara Sea, Russia; ~700 mm SL. A. Konovalov

Further reading. Shaposhnikova, 1968 (systematics); Holčík et al., 1988 (biology); Zinoviev et al., 1997 (Kama, distribution, protection); Danilov-Danilyan, 2001 (conservation); Froufe et al., 2003 (genetics); Ocock et al., 2006a-b (conservation).

Oncorhynchus gorbuscha

Common name. Pink salmon.

Diagnosis. Distinguished from *O. mykiss* by: ● 11–15½ (usually 13½) branched anal rays / ● 177–240 total scales in midlateral row / ● 26–33 gill rakers / ● large mature males with enormous hump / ● juveniles without parr marks / ● no pink to red stripe on flank. Size up to 760 mm SL and 5.5 kg.

Distribution. Native to northern Pacific basin in Russia, Japan, North China and North America. Original (freshwater) spawning grounds ranged from central California to near River Mackenzie in Arctic Canada and, on Asian side, from North Korea to Jana and Lena drainages in Arctic Russia. In Bering Sea north of about 40°N and from Bering Strait northeast to Point Barrow and northwest to Lena estuary. In 1956–78, over 200 million eggs were shipped from Sakhalin Islands to Kola Peninsula (Murmansk region) and White Sea. Now established in that area, especially odd-year lineage. Regular adult returns are known north to Rivers Tenojoki and Näätämöjoki (Finland, Norway) and east to Yenisei. Occasionally found in North Sea and northern Atlantic (Iceland, Scotland). Introduced into Black and Baltic Seas without success.

Habitat. At sea, pelagic; in freshwater, montane and piedmont rivers with moderate to fast current and gravel bottom. Spawns in riffles or at head of riffles, in shallow water with current up to 1.5 m/s, clean coarse gravel.

Biology. Anadromous. Spawns at 2 years. Exhibits a fixed two-year life cycle; in a given river system, populations spawning in odd and even years are reproductively and genetically isolated. Adults begin to appear near shore in June – September. Undertake short spawning migrations into rivers, often remaining within a few km from sea. When approaching full sexual maturity, males develop striking secondary sexual characters, including a hump, an enlarged head, and large teeth on both jaws that form a pronounced hooked kype. Spawns in August – November, in dense aggregations in riffles. Males are polygamous. Females select redd site and proceed with digging and preparing one to four nests 20–40 cm apart which form a redd when all eggs are laid. The size of the redd varies from 60 to 150 cm in width and 100–250 cm in length. Redd area is defended by the female and the dominant male. Females lay 50–1200 eggs, 5–7 mm in diameter, per nest. Spawners die 10–20 days after spawning. Eggs hatch in 100–120 days at about 4°C. Fry emerge from redds in April – June and quickly migrate to sea. Juveniles feed mainly on larvae and pupae of Diptera in freshwater, and calanoids, harpacticoids and mysids at sea. At 1 year, they feed on fish, squid, euphasiids, and amphipods. Feeding is reduced when maturing individuals arrive in coastal waters and prepare to move into streams, after about 18 months at sea.

Conservation status. Alien, invasive.

Remarks. Russian fisheries biologists have tried to introduce several species of Pacific salmons from Sakhalin Island to the White Sea basin since 1956. Sakhalin *O. keta* were also released in the Volga drainage and North American *O. kisatch* was stocked in several lakes of Germany, the Netherlands and possibly other countries. The introduction of *O. keta*, *O. kisatch* and *O. tshawytscha* failed. *O. kisatch* is apparently still farmed in Spain and individuals escape from aquaculture. *O. kisatch* is often misspelled *O. kisutch* and *O. tshawytscha* is often misspelled *O. tschawytscha*.

Further reading. Heard, 1991 (biology).

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Rainbow trouts in Europe

Eggs of *Oncorhynchus mykiss* were first imported in 1882 to Germany. They were of hybrid origin (anadromous steelhead and resident rainbow from River McCloud, Sacramento drainage, California). Offspring of these first fishes were distributed throughout Europe but eggs from different origins were imported several more times from North America. Stocks with different spawning seasons were mixed, crossed and selected in order to produce trout of the same market size at all seasons. The rainbow trout cultivated in Europe is a true domesticated species, with little in common with its wild ancestors. It is the most important freshwater fish next to *Cyprinus carpio* in European aquaculture and is produced throughout Europe in coldwater streams. Different varieties have been developed, spawning from September until April. Some strains grow very fast, reaching maturity at one year and are very much adapted to pond conditions. Stocking into natural waters is still practised in some countries, whereas it is prohibited in others. In North America, rainbow trout may be anadromous and migrate to sea to forage (steelhead trout). In northern Europe, rainbow trout is commonly cultivated in marine and brackish waters. Steelhead trout spawning was recently observed in Norway and it is expected that the species will spread across northern Europe.

In most areas, stocks of *O. mykiss* are maintained only by regular stocking of hatchery-reared fishes but many self-sustaining populations have become established in alpine streams of Austria, Slovenia and probably elsewhere too. This is or may become the case in other hill streams of central, northern and southern Europe (natural production is apparently not observable in many areas because it is masked by stocking).

This species has long been known as *Salmo gairdneri*, *S. irideus* or *Parasalmo gairdneri*. It is now placed in the genus *Oncorhynchus*, which includes several species of Pacific salmons and cutthroat trouts and related species from northern America and northeastern Asia. In addition, *O. gairdneri* and several other northern American stocks are treated as conspecific with *O. mykiss*. These synonymies are questioned by some researchers and more changes should be expected. As a usable species level revision is not available, we refrain from changing the names at this stage. But we note that some authors consider the cutthroat and rainbow trouts (*Parasalmo* or *Rabdofario*, the name of a fossil trout, which is possibly congeneric) as belonging to a genus distinct from the Pacific salmons (*Oncorhynchus*) and that, under the species concept used here, *O. mykiss* seems to be a species endemic to Kamchatcka (as recognized by Russian authors). If that proves correct (which seems likely), *O. gairdneri* might be the name of most of the rainbow trouts in European waters. It is not clear, however, how many species have been introduced for aquaculture purposes and are now mixed. The true *O. mykiss* of Kamchatka is a threatened species; confusion with a cultivated species creates an additional threat to its survival because of the misleading impression of there being no conservation concern.

Some farms in Sweden and perhaps elsewhere apparently have bred cutthroat trout (*O. clarkii*) and this species is recorded in the list of Swedish freshwater fishes. There are no recent records of this species in European waters but we cannot exclude the possibility that it is still present. It is distinguished from *O. mykiss* by a prominent red mark below the lower jaw (vs. no such mark).

Oncorhynchus mykiss

Common name. Rainbow trout.

Diagnosis. Distinguished from *O. gorbuscha* by: ● 6–9½ (usually 8½) branched anal rays / ● wide, pink to red stripe from head to caudal base (except in sea-run form) / ● 115–130 total scales in midlateral row / ● 16–17 gill rakers / ● breeding males without hump / ● juveniles with 5–10 parr marks. Size up to 1000 mm SL.

Distribution. Native to Kamchatka and south to lower Amur drainage, and Pacific basin of North America south to northern Mexico. Established in few Alpine rivers in Austria, Slovenia, Switzerland and in Serchio drainage (Italy).

Habitat. Stocked in almost all water bodies as lakes, rivers and streams. Usually not stocked in water reaching summer temperatures above 25°C or ponds with very low oxygen concentrations. Spawns in gravel in fast-flowing water.

Biology. Anadromous, lacustrine and resident life history forms. Often spawns for the first time at 1 year, at 3–5 years in the north. Usually spawns in February – May when temperatures rise above 10–15°C. Farmed trouts are mature between August and April, depending on the strain. Undertakes short spawning migrations. Anadromous and lake forms may undertake long migrations to spawning streams. Females construct redds in gravel bottom of moderate to fast-flowing streams or rivers. Does not establish breeding populations if the peak

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Oncorhynchus mykiss; aquaculture, Germany; ~400 mm SL. A. Hartl

emergence of fry corresponds to flood season and cold summer temperatures and if temperature does not fall below 13°C. In agonistic behaviour, *O. mykiss* fry dominates *Salmo* fry of similar size. Feeds on a wide range of aquatic and terrestrial invertebrates and small fish. At sea, feeds on fish and cephalopods. Feeding is negligible below 5°C and above 25°C.

Conservation status. Alien.

Further reading. Smith & Stearley, 1989 (systematics, nomenclature); Behnke, 1992: 193 (diversity); Stearley & Smith, 1993 (phylogeny); Zelinsky & Makhrov, 2001 (chromosomes); Fausch et al., 2001 (invasion success).

Salmo

We insists that the following is not a revision of the genus but a taxonomist's evaluation of the data (published or not) available to us. Even if very different from the proclaimed "accepted" system used by geneticists and fisheries biologists, because of the lack of key information and material, we have been very conservative in the number of species we recognize.

Diversity of trouts is generally underestimated because life history traits confuse the picture. The life history of trout species follows several similar patterns. Classically, three 'kinds' of trouts have been recognized:

1) anadromous trout (sea trout). They are born in streams, smoltify and migrate to the sea or to estuaries to forage, then return to their native stream to spawn. These are often called '*S. trutta* forma *trutta*', which is an incorrect name (see below).

2) lake trout (some are landlocked populations of anadromous species, some are derived from resident populations). They are born in streams, smoltify and migrate to the lake to forage and return to their native stream to spawn. They are usually called '*S. trutta* forma *lacustris*', which is also an incorrect name.

3) In nearly all spawning streams, some individuals do not migrate and remain there as, so-called, resident trout. Some population may include only resident, non migratory individuals. They are usually called '*S. trutta* forma *fario*', which is an incorrect name as well.

These different life history forms of trouts are not reproductively isolated. In some species, only the resident and/or the lacustrine forms are known. In others, all three forms occur and all their offspring seem potentially to have the ability to smoltify and migrate to foraging habitats.

There are variations on these general lines. In a few drainages, resident and anadromous individuals have been reported to belong to independent, genetically isolated lineages living in sympatry (that is, behaving as distinct species). There are probably environmental conditions determining the life history strategy that an individual trout will follow and which life history it will develop; but there are also genetic factors that seem to determine whether or not some species or populations have the potential to develop different life histories. This plasticity of life history strategies is known in some populations (not all!) of *S. trutta*, and has been reported also for *S. labrax* and *S. ciscaucasicus*.

In some lakes, there are sympatric 'kinds' of trouts, which are reproductively isolated, differ morphologically, have different life histories (different feeding habits, preferred habitats, spawning sites, spawning seasons). Their offspring develop only the 'kind' of their parents and these are clearly different species. It is not known whether they evolved in sympatry in the lake they presently inhabit, or if they evolved elsewhere and independently colonised the lake. If they evolved in sympatry, then they can be considered as species

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Species flocks

A species flock is an accumulation of a relatively large number of closely related species confined to a narrowly circumscribed area. Species flocks are typically encountered in lakes, on mountain ranges and on islands. In a given area, the number of species of a given genus or family is much higher than observed for the same group in other similar-sized areas. For example, Lake Baikal is inhabited by 12 genera and 28 species of sculpins (Cottidae), while everywhere else in the world at most 2 or 3 species would occur in sympatry. What makes a species flock is not the absolute number of species, but their relative number. Species flocks in African lakes include several hundred species, while the *Cyprinodon* flock of Laguna Chichancanab (a series of eight small lakes with a total area of about 15 km^2 in Yucatan) counts only six species.

There is discussion among evolutionary biologists on whether or not an assemblage of species should be monophyletic to be considered a species flock. Some authors place emphasis on the ecological or functional phenomenon of explosive speciation and radiation within a geographically closed area. In this perspective, the accumulation of narrow specialisations is the main concern, and the strict monophyly of the flock(s) is less relevant. This is the original concept of a species flock.

Others, who focus on the phylogenetic aspect, consider that only strictly monophyletic lineages qualify as species flocks; that is, all species of the flock are derived from a single ancestor and all descendents of this ancestor lie within the flock. Under this definition, the cichlids of Lake Tanganyika would not belong to a single but to several flocks as some genera in the lake are more closely related to lineages outside the lake than to those in the lake.

Members of a species flock have often evolved (e.g.) morphological, ethological, feeding, reproductive specialisations, and therefore have different ecologies, at least at some time of the year. The most diverse fish species flocks are the cichlids of the great African lakes (Victoria, Malawi, Tanganyika) whose members include benthic as well as pelagic species, feed on fish, algae, invertebrates, fish fins, fish eggs and fish scales, and spawn on exposed rocks, in burrows, in empty snails, in nests of other species, etc. In other species flocks, the morphological differences between members may be minimal, at least for our human eyes (as in *Coregonus*). Fish species flocks usually co-occur with flocks of other groups of animals (especially molluscs and crustaceans). Also, if the strict monophyletic definition is used, several fish species flocks may co-occur in one lake, as in Lake Tanganyika.

Where several endemic species of Salmonidae and Coregonidae occur in sympatry in a single lake or small drainage, they may qualify as species flock if they constitute a monophyletic lineage. Most likely, species flocks evolved in several European lakes: for example, the charrs of Lake Thingvallah, the coregonids of Alpine lakes and perhaps also those of Lakes Ladoga, Onega, Vänern and others, and the trouts of Lake Melvin.

Other examples of fish species flocks include the Cyprinidae of Lake Lanao (Philippines), the Cottidae of Lake Baikal, the Adrianichthyidae and Telmatherinidae of various lakes in Sulawesi (Indonesia), the *Orestias* toothcarps of Lake Titicaca (Peru, Bolivia).

Further reading. Greenwood, 1981; Echelle & Kornfield, 1984; Kottelat, 1990a,c, 1991; Seehausen, 1996; Seegers & Tichy, 1999.

flocks. Cases of sympatry are known from Lough Melvin (3 species), Lough Neagh (Ireland) (2 species) and Lake Ohrid (Albania, Macedonia) (4 species, but there is still uncertainties as to their status). Outside Europe, the trouts of Lake Sevan (Armenia) apparently constitute one more case. Single endemic trouts are known from Italy in Lake Garda (*S. carpio*) and Lake Posta Fibreno (*S. fibreni*). In lake Garda, *S. carpio* occurs in sympatry with a lake-form of a more widely distributed species. More lakes with endemic trout species or species flocks probably exist. It is surprising that no such case is actually known from subalpine lakes, but the case of the lake trouts of Lakes Constance and Geneva still deserve critical re-evaluation and there are indications that some lakes actually do host morphologically distinct 'forms' (there are indications that more species might have existed but are now extinct; see account of *S. schiefermuelleri*). In the Mediterranean basin, trouts are not known to migrate to the sea; it is not known whether they have lost the genetic ability to develop alternative life history traits, whether they result from a lineage that had not developed that possibility, or whether the environmental factors triggering smoltification are absent today. This possibly explains why populations have been more or less isolated in their individual drainages,

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why the number of species is greater in southern Europe, and why the ranges of each species are smaller. Sea trouts have long been exceptional findings in the Mediterranean basin. Recent records of anadromous trouts in Rhône drainage are based on introduced *S. trutta* and not on the native *S. rhodanensis*.

In many areas, resident trout populations are usually very difficult to distinguish and the number of species considered here as valid is still tentative. Despite the large number of published studies, the quantity of data usable in a systematic framework is extremely limited.

Nomenclature. Under the International Code of Zoological Nomenclature it is not correct to use names like *S. trutta* forma *fario*, *lacustris*, etc. Names of varieties, forms, etc. are not part of the scientific name of an animal and should never be italicised. In fact such pseudo-scientific, Latin-like names are misleading and should be avoided. The use of a wording like '*S. trutta* anadromous form' or '*S. trutta* sea trout form' are nomenclaturally, linguistically and semantically more correct.

In addition, the name *S. trutta trutta* cannot be used for the anadromous individuals (as is currently done). If the sea trout is recognized as a distinct species, the name *S. trutta* has to be used for a riverine trout and not to the sea trout.

Morphological and molecular data show that *S. salar* constitutes a lineage separate from all other species of the genus, themselves forming two lineages, one being the brown trouts and the other made of two Balkan species *S. obtusirostris* and *S. ohridanus*. We retain them in a single genus, but they could as well be treated as three genera.

Further reading. Kottelat, 1997 (systematics); Bernatchez, 2001 (genetics); Sušnik et al., 2006 (genetics).

Atlantic basin

Two species of *Salmo* are traditionally recognized in the Atlantic basin, the salmon *S. salar* and the Atlantic trout *S. trutta*. *S. trutta* is the correct name for the anadromous Atlantic trout and the resident and lacustrine populations directly derived from it. On the basis of published data, we retain most trouts from the Atlantic basin in continental Europe as belonging to a single species, although this assertion clearly needs to be re-evaluated. The exceptions are the trouts retaining parr marks in adults (at least up to about 220 mm SL) of the northern Pyreneean slope and Iberian Peninsula (see discussion under *S. cettii*). Although there is information on molecular characteristics of these populations, there is about no published usable information on their appearence, morphology and colour pattern.

The number of trouts inhabiting the British Isles is uncertain. There are three well-documented species in sympatry in Lough Melvin (Ireland). They differ in external morphology and coloration, spawning sites and feeding habits and are reproductively isolated. Therefore they fulfil the criterria for recognition as species under any species concept. Several populations outside the lake possibly are conspecific with one or the other of these species. The literature suggests a possibly similar situation in Lough Neagh, but the published data are insufficient to allow a conclusion. The problem is not so much to distinguish the lacustrine species where they occur in sympatry but to know whether and where they occur outside the lakes and to clarify the identity and diversity of the riverine populations. There are possibly more species hidden under the catch-all name *S. trutta*.

Salmo ferox

Common name. Ferox trout.

Diagnosis. Distinguished from other species of *Salmo* in British Isles by: ○ body brown to silvery, black spots small (equal to or smaller than pupil), few or absent / ○ large size / ○ maxilla reaching beyond posterior margin of eye / ● body depth about 4.6–5.0 times in SL. Size up to about 800 mm SL.

Distribution. British Isles: Loughs Melvin, Erne, Corrib and Mask (Ireland), Lochs Awe, Laggan and others (Scotland), apparently also Lakes Ullswater and Bassenthwaite (Cumbria) and Llyns Padarn and Peris (Wales).

Habitat. Large oligotrophic lakes; in Scotland usually only in lakes inhabited by *Salvelinus* species on which it preys. Spawns only in the larger and deeper tributaries.

Biology. Lives up to 23 years. Spawns in November – December. Feeds on fishes and a variety of insects. In Scotland, feeds on invertebrates until about 300 mm SL, then switches to a fish diet, mostly *Salvelinus* species.

Conservation status. DD.

Remarks. Several populations of large, piscivorous trouts from Ireland, northern Scotland, Cum-

Salmo ferox

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Salmo ferox; Loch Melvin, Ireland. A. Ferguson

Salmo nigripinnis; Loch Melvin, Ireland. A. Ferguson

bria and Wales are called ferox trouts. They are recognized as a distinct species on the basis of their existence in sympatry with genetically distinct *S. trutta* in several lakes, but it remains to be demonstrated whether all ferox trouts are conspecific. Further, some individuals or populations might be old, large, piscivorous, lacustrine *S. trutta*.

Further reading. Campbell, 1979 (biology, Scotland); Ferguson, 1986 (biology); Ferguson & Taggart, 1991 (genetics); Duguid et al., 2006 (genetics).

Salmo nigripinnis

Common name. Sonaghen.

Diagnosis. Distinguished from other species of *Salmo* in British Isles by: ○ body light brown to silvery with many large black spots / ○ red spots absent or few, small, inconspicuous, restricted to posterior part of body / ● fins dark brown or black, especially pectorals / ○ body depth about 3.9–4.4 times in SL. Size up to about 330 mm SL.

Distribution. Ireland: Lough Melvin (21 km^2).

Habitat. Lacustrine, pelagic, in relatively deep water. Moves to tributaries for spawning.

Biology. Spawns in November – December in most lake tributaries. Feeds mainly on mid-water plankton, especially Cladocera, and chironomid pupae.

Conservation status. VU D2*.

Further reading. Ferguson, 1986 (biology); Ferguson & Taggart, 1991 (genetics).

Salmo salar

Common name. Atlantic salmon.

Diagnosis. Distinguished from other species of *Salmo* in Atlantic, North, White, Barents and Baltic Sea basins by: ● 10–13 scales between end of

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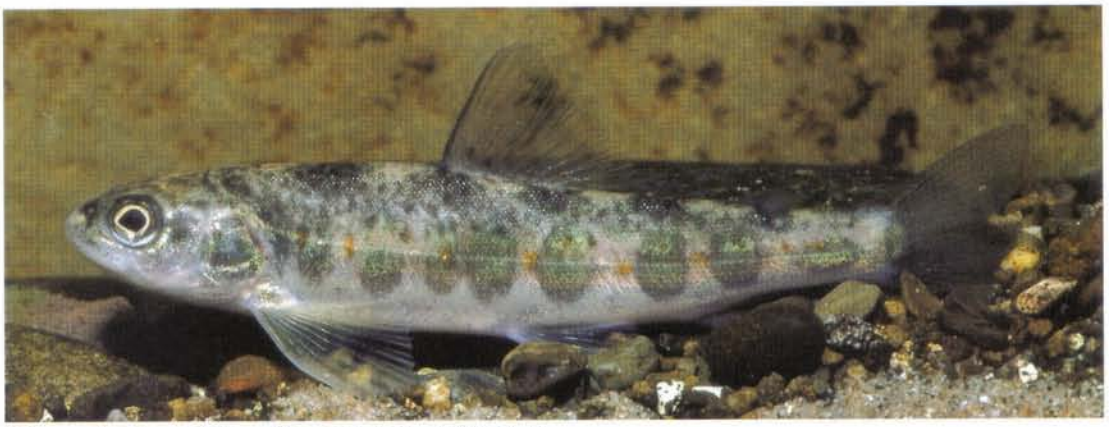

Salmo salar; lower Rhine, Germany; parr, ~100 mm SL.

Salmo salar; Ireland; marine phase, ~750 mm SL. A. Hartl

Salmo salar; upper Elbe drainage, Germany; freshwater phase, male, ~700 mm SL. W. Fiedler

adipose base and lateral line / ● 17–24 gill rakers. Additional characters distinguish salmon parrs from trouts: ● caudal deeply forked in individuals smaller than 200 mm SL / ● hyaline or grey adipose margin. Additionally, adult salmon are distinguished from sea trout by: ● posterior part of vomer toothless (Fig. 73b). Size up to 1000 mm SL.

Distribution. Atlantic, North, White, Barents and Baltic Sea basins, from Minho (Portugal, Spain) to Kara drainages (Kara Sea, Western Siberia). Present in Iceland and in northernmost rivers of Great Britain and Scandinavia. Landlocked populations known from southern Finland, Lakes Vänern (Sweden), Ladoga, Onega, some small lakes in Vyg and Kem drainages, White Sea basin (Russia) and from southern Norway. Main foraging areas along west coast of southern Greenland and north of Faroe Islands. Baltic populations do not leave this sea. Historical records from Duero, Tagus and Guadiana (Portugal, Spain) where now extirpated. Introduced to New Zealand, Chile and southern Argentina.

Habitat. All rivers where temperature rises above

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Salmo salar; Norway; freshwater resident; ~350 mm SL. A. Hartl

10°C for about 3 months per year and does not exceed 20°C for more than a few weeks in summer. Juveniles and resident stream populations inhabit riffles of fast-flowing, moderately cold streams and rivers. In northern Europe, juveniles may live in cold lakes. Spawns in rivers and streams with swift flowing water and succession of riffles and pools. Lacustrine populations migrate to tributaries. Usually spawns at tail of pools in gravel. Pelagic at sea or in large lakes, mostly foraging in surface layers.

Biology. Anadromous and landlocked populations. Spawns in couples in October – January (October in Norway and Russia, November in Germany, Denmark and southwestern Sweden; December in Ireland, France and Spain). Translocated stocks retain their original spawning time. Females select spawning sites and dig the redds. Males guard and defend females against other males. An individual female may dig up to six redds and both sexes may mate with several partners. Spawns into the redd depression and eggs are covered with gravel by the female. Most males die after reproduction, while 10–40 % of females kelts may survive spawning and migrate back to sea in autumn or overwinter in rivers , feed one summer, and migrate again. Neither sex feeds in freshwater during the spawning and post-spawning migrations. Usually, 0.3–6 % of females reproduce a second time. Kelts may spawn in the year following the first reproduction or may remain at sea for 18 month before returning once more to the river. In short rivers, up to 34 % of the individuals reproduce a second time and there are records of individuals spawning for up to six seasons. Eggs are covered with 10–30 cm of gravel and hatch in 70–160 days. Successful development of eggs and alevins requires a water permeability through gravel above 1 m/h. Alevins are negatively phototactic and move deep into gravel. Fry are positively phototactic and inhabit very shallow riffles, downstream of spawning site. Fry usually emerge from gravel between March (Spain) and July (north Finland) when temperature rises above 8°C.

Parrs are territorial, feeding on drifting and benthic invertebrates. Some males may spawn for the first time when still parrs and are then able to fertilise more than 20 % of eggs by sneaking into redds of anadromous couples. Mature parrs are also able to fertilise eggs of females in the absence of anadromous males. Mature male parrs usually migrate to sea but have a lower probability of returning to breed as adults than males that did not mature as parrs. Some parrs may remain in freshwater. Ripe female parrs are very rare. A few

Salmo salar; Rhine, Germany; spawning male, ~650 mm SL.

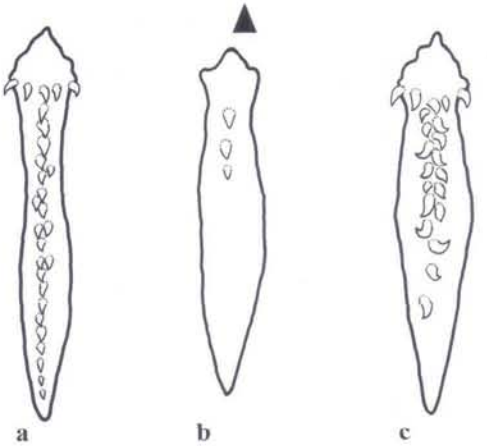

Figure 73 Vomer (ventral view) of: **a,** *Salmo ohridanus*; **b,** *S. salar*; **c,** *S. trutta*. Arrow points towards head.

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Salmo stomachicus; Loch Melvin, Ireland. A. Ferguson

landlocked stream populations maturing as parrs are known from Norway, in streams where waterfalls prevent access to anadromous salmons. Parrs feed for 1–7 (usually 2–3) years in freshwater depending on temperature and feeding conditions. Usually, parrs smoltify at 100–150 mm SL; smoltification is triggered by increasing day length in winter. Smolts start to migrate downstream in April – June when temperature increases from low winter level, rising above 8–10°C. Migration peaks when rising water level coincides with increased turbidity during spring floods or heavy rain. A small number may migrate to sea in autumn. Smolts are gregarious and migration is nocturnal with peaks at dusk and dawn. Learning the route during downstream migration seems to be the main factor determining successfull homing. Smolts may spend some time in brackish estuaries or they may immediately move to sea. At sea, pelagic and feeding on small fish and large crustaceans such as amphipods and euphausids. After spending 1–4 winters at sea, migrates to its natal river. Pattern of upstream migration depends on particular river, sex and age. Individuals may enter rivers in any month of the year, some enter more than a year before spawning. Usually, individuals that had spent more than one winter at sea seem to enter rivers in spring while those that spent a single winter at sea dominate the autumn run. A number of individuals enter the wrong river. During upriver migration, silvery colour of marine phase is replaced by a dark breeding colour; the skull of males enlarges and they develop a kype on lower jaw. Sometimes hybridises with *S. trutta*.

Conservation status. VU A2ce*. Strongly affected by water pollution, damming and overfishing. Because of degraded environmental conditions, most populations depend largely or exclusively on stocking. Due to intensive farming, the fishing pressure on wild stocks has decreased but other problems have increased. Farmed salmons are domesticated animals and are usually the result of hybridisation of different stocks with selection favouring farm conditions. Large numbers of farmed salmons escape and - as they have no homing site - move to any river and hybridise with wild stocks. Usually egg and juvenile survival rates are much less than in wild salmon and thus farm escapees drain the reproductive success and pollute the genetic and adaptive identity of wild populations. Sea lice *Lepeophtheirus salmonis*, an ectoparasitic copepod, occur in large numbers on captive salmons and seriously infect wild smolts, as they migrate through salmon farms in estuaries. The introduction of the monogenetic trematode *Gyrodactylus salaris* from Baltic farmed salmons to Norwegian wild stocks has caused mass mortalities. *G. salaris* is a freshwater ectoparasite on parrs; it is spread by salmon eggs or parrs (or trouts) used for stocking. In some rivers, Norwegian fisheries authorities killed all fish (not only salmon but the whole population of all native non-anadromous species was eradicated) with ichthyocides to get rid of this parasite. In addition, overfeeding in farms and use of chemicals and/or antibiotics result in local pollution.

Remarks. European and North American salmons have long been considered as a single species but they are distinguished by chromosome numbers and molecular characteristics. Their status should be re-evaluated.

Further reading. Kottelat, 1997: 138 (systematics); Mills, 2000 (biology); Klemetsen et al., 2003 (life history).

Salmo stomachicus

Common name. Gillaroo.

Diagnosis. Distinguished from other species of *Salmo* in British Isles by: ○ body and fins golden brown to yellow, with many black spots / ○ many large vivid orange-red spots, especially on and below lateral line / ○ body depth about 3.3–3.8 times in SL. Size up to about 360 mm SL.

Distribution. Ireland: Lough Melvin (21 km^2); possibly other lakes of Ireland and Scotland.

Habitat. Lacustrine, in shallow waters. Spawns

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Salmo trutta; Sorne, Rhine drainage, Switzerland; resident form, 210 mm SL.

near or in lake outlet. May also spawn on sandy bays in middle region of northern shore.

Biology. Spawns in November – December. Juveniles swim upstream to return to lake. Feeds primarily on snails and trichopteran larvae, supplemented by other benthic invertebrates.

Conservation status. VU D2.

Remarks. Similar trouts have been recorded from Loughs Neagh, Conn and Corib (Ireland) and from Lochs Fadagoa, Mulach-Corrie and Assynt (Scotland). There are no data that allow a conclusion on whether they are conspecific with the Melvin ones. The above diagnosis is based on the Melvin population only.

Further reading. Ferguson, 1986 (biology); Crozier & Ferguson, 1986 (genetics); Ferguson & Taggart, 1991 (genetics).

Salmo trutta

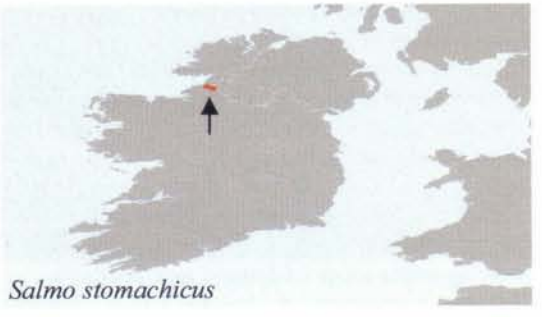
Common name. Atlantic trout.

Diagnosis. Distinguished from other species of *Salmo* in Atlantic, North and Baltic Sea basins by: O caudal emarginate in individuals smaller than 200 mm SL, often truncate in larger ones / O 13–16 scales between end of adipose base and lateral line / O 14–16 gill rakers / O maxilla reaching to or beyond posterior margin of eye / O posterior part of vomer toothed in adults (Fig. 73c) / O orange or red adipose margin in juveniles and resident adults. Size up to 900 mm SL. Anadromous and lacustrine individuals usually 450–600 mm SL, resident stream individuals usually 200–300 mm SL.

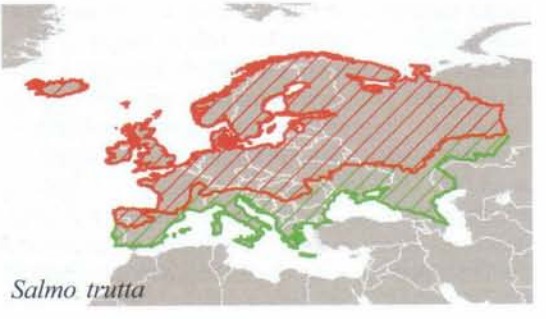
Distribution. Atlantic, North, White and Baltic Sea basins, from Spain to Chosha Bay (Russia). Present in Iceland and in northernmost rivers of Great Britain and Scandinavia. In Rhône drainage, native only to Lake Geneva basin, which it entered after last glaciation. Native to upper Danube and Volga drainages. Introduced throughout Europe, North and South America, southern and montane eastern Africa, Pakistan, India, Nepal, Japan, New Zealand and Australia.

Habitat. Cold streams, rivers and lakes. Spawns in rivers and streams with swift water. Lacustrine populations migrate to tributaries and lake outlets to spawn, rarely spawning on stone, wave-washed lake shores. Spawning sites usually characterised by downward movement of water into gravel. Sea and lake trouts forage in pelagic and littoral habitats, sea trouts mostly close to coast, not very far from estuary of natal river.

Biology. Anadromous, lacustrine and resident forms. Spawns in couples between late October and March, usually in November – December. Females select spawning sites and dig the redd. Males guard and defend females against other males. Eggs are covered with gravel by female. Both sexes usually survives spawning and anadromous trout migrate back to sea or lake in autumn or overwinter in rivers and migrate in spring (5–70 % repetitive spawners in Norway). Sea trouts gener-



Salmo stomachicus



Salmo trutta

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Salmo trutta; lower Rhine, Germany; ~80 mm SL.

Salmo trutta; Danube drainage, Germany; resident form, ~250 mm SL. A. Hartl

Salmo trutta; Danube drainage, Germany; resident form, ~350 mm SL. A. Hartl

Salmo trutta; Danube drainage, Germany; resident form, ~500 mm SL. A. Hartl

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Salmo trutta; Lake Chiemsee, Germany; lacustrine form, ~450 mm SL. A. Hartl

Salmo trutta; lower Rhine, Germany; marine form, smolt, ~250 mm SL. I. Steinmann

Salmo trutta; Orkney Islands, Scotland; resident form.. A. Ferguson

Salmo trutta; Loch Crocach, Scotland; resident form. A. Ferguson

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Salmo trutta; Danube drainage, Germany; resident ecotype, nuptial male in front, ~300 mm SL. A. Hartl

ally feed in freshwater. Eggs are covered with 3–30 cm of gravel. Redd depth is positively related to female's size. Eggs in deep redds are less vulnerable to spates and wash-outs and more vulnerable to low oxygen concentrations and pollution. Fry usually emerge from gravel between March (Spain) and July (Finland).

Parrs and resident trouts are territorial, feeding on drifting and benthic invertebrates. Success in finding and defending a feeding territory is positively correlated to size of fry and to mother's size. Being large is clearly advantageous at this stage of life cycle. Resident trouts usually spawn for the first time at 2–3 years and spawn 2–3 seasons. Smoltification usually complete at 2–3 years and 120–220 mm SL, but up to 7 year old smolts are reported. Mean smolt age increases with latitude. All juveniles seem to have the genetic ability to smoltify and migrate; in some small, summer-dry streams all migrate. In other streams, almost none seem to migrate. Factors triggering the 'decision' of an individual to smoltify or not are not well understood. If migration is impossible, smolts may interrupt migration and become resident again. In most rivers, a greater proportion of females than males seems to migrate, apparently a response to a greater need for reproductive energy. Therefore, sex ratio is usually skewed towards females in smolts. Large anadromous females may spawn with small resident males (the reverse is not reported but is expected to be possible, too). Smolts start to migrate downstream in April – May when temperature increases from low winter level, reaching beyond 5–11°C; migration peaks at rising water levels with increased turbidity.

There is a great variability in life history details of lacustrine populations. In some lakes, fry may migrate to the lake and at least males may spawn for the first time at 2 years. In other lakes, parrs smoltify after spending 1–3 year in spawning streams and males feed 4–6, females 5–8 years before first reproduction. At sea and in lakes, trouts feed on small fish and large crustaceans. In lakes, aquatic and terrestrial insects may form an important part of the diet. After at least 18 month at sea, sea trouts start to return to rivers to spawn. The pattern and timing of upstream migrations depends on particular river, sex and age. Homing accuracy is not as high as in *S. salar*. After spending one summer at sea, whitling start to migrate in July – September to lower reaches of rivers to overwinter or mature and migrate to spawning sites. Anadromous adults migrate in May and enter rivers until late October. Most maturing whitlings are males and the proportion of whitlings might be up to 30

Salmo trutta; Danube drainage, Germany; development stages; from top to bottom: alevin and empty egg shell, fry, and parr. A. Hartl

watermanⓒ

Trout taxonomy: the shame of European ichthyology

Trouts are 'the' fish that most anglers prize throughout Europe. They are the main (if not the sole) concern of a number of fisheries agencies and associations. They have been the cause of most fisheries 'management plans' in many countries. They are produced in huge quantities. They have been the subject of innumerable studies. They have attracted the attention of hordes of geneticists. Nevertheless, all this 'interest' has resulted in very little data usable in a taxonomic framework. In 2007, trout taxonomy in most of Europe is still handled in a way that would be considered non-professional anywhere else and for any other group of animals.

In the cases when the data make sense, their usefulness is very limited (or even nullified) by the absence of voucher material on which the identity of the analysed material can be checked or confirmed. Some are accompanied by 'morphological' studies in which the authors merely counted red and black spots, which is a strange understanding of 'morphology'. To pretend to contribute anything towards solving taxonomic problems, a genetic study *must* be accompanied by information on the examined material, these individuals must be properly fixed (not dumped carelessly in a freezer or in a tiny vial with a few drops of ethanol), deposited in a natural history museum with facilities to make them available for future examination by other researchers, and access to this material must be permitted. If these minimum conditions are not satisfied, genetic, phylogenetic and phylogeographic studies represent little else than wasted money and effort, with the fish used for these researches having been sacrificed for no justifiable reason.

% among spawners. Whitlings usually sneak in to spawn in redds of large couples, as resident males do, too. Large males attack, injure and often kill sneakers. After one spawning season as whitling or resident male, individual trouts may spawn again as large sea trout. The factors triggering the 'choice' to reproduce as whitling or as large male seems to be related to body size of young parrs since larger parrs more frequently develop the whitling tactic and smaller parrs the large male tactic. During upriver migrations, the silvery colour evolves into a dark breeding colour, the skull of males enlarges and the lower jaw develops a kype. Sometimes hybridises with *S. salar*.

Conservation status. LC, anadromous part of populations and many lacustrine stocks have in many cases markedly declined because of pollution. Phylogeographic structure almost destroyed by stocking.

Remarks. Genetic data indicate that *S. trutta* and some populations of hybrid origin are native in some rivers draining to the Mediterranean, the Black Sea (at least in upper Danube drainage) and the Caspian Sea (at least in upper Volga drainage). The present published data do not always enable to distinguish the head water populations of the different species on the basis of morphological characters (they may be distinguishable, but this simply has not been investigated).

Further reading. Elliot, 1994 (ecology); Bernatchez, 2001 (phylogeography); Klemetsen et al., 2003 (life history).

Western Mediterranean basin

Genetic data show that Mediterranean trouts belong to lineages very distinct from Atlantic and Danubian trouts. Numerous species have been recognized among Mediterranean trouts, unfortunately most of these descriptions are laconic and uninformative making it difficult or impossible to compare populations from different drainages. On the basis of the available literature and our own examination of museum and fresh material, we tentatively recognize several species. Some have very diagnostic characters while for others we are unable to test the characters mentioned in the literature due to the lack of access to comparison material. Often, stocked material has hybridised with the local species, making it difficult to recognize the original characters.

Trouts that retain the parr marks in adults are known from Iberian Peninsula, northern Pyrénées, Corsica, Sardinia, southern Italy, Greece, Turkey, Algeria and Morocco and have usually been called *S. macrostigma*. This name cannot be applied to any European trout species for two reasons: 1) if all peri-Mediterranean trouts with large parr marks in adults are considered to belong to a single species, then the name *S. cettii* is much older and has priority; 2) if the Algerian trouts are considered to be specifically distinct from the European ones, then the name *S. macrostigma* can only be used for (some of) the North African ones. In the absence of comparative study, we tentatively retain the *'macrostigma'* trouts of Sicily, Sardinia, Corsica and Italy as conspecific (with the valid name *S. cettii*). Recent molecular studies, however, suggest that the case will need re-examination (see

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Salmo carpio; Lake Garda, Italy; ~350 mm SL. B. Delling

under *S. cettii*).

The data for the Balkan trouts are still very incomplete. The ' *macrostigma*' trouts from the Balkans seem to represent one or several distinct species for which the oldest name is *S. farioides*, and those from northern Pyrénées (Adour and southern Garonne tributaries, Atlantic basin; Aude, Mediterranean basin) possibly constitute one or more unnamed species. Photographs of Ebro and Cantabric populations suggest that they could be identical with or closely related to the North Pyrenean species; they retain the parr marks until at least 220 mm SL. Photographs of Douro and Tagus populations suggest a species somewhat similar to *S. rhodanensis* but with blurred bars on body. Photographs of Guadalquivir populations suggest a distinct species possibly related to some North African species. The Corsican trouts Because of a lack of data and comparison material, these species cannot be discussed separately and could not be included here.

In the Mediterranean basin, native *S. trutta* only occur in the Rhône drainage upstream of Geneva, which they colonised after the last glaciation; *S. rhodanensis* has been unable to overcome the gorges and rapids immediately downriver of the lake.

In the absence of material, we gave the benefit of the doubt to some species and consider them as valid, pending availability of usable material or data.

Further reading. Schöffmann, 2002 (Iberian populations); Delling & Doadrio, 2005 (North African species).

Salmo carpio

Common name. Carpione.

Diagnosis. Distinguished from other species of *Salmo* in Italy by: ○ adults without parr-marks / ○ outside spawning season silvery, with few, very small dark spots on body; during spawning season, some males show a dark marbled colour pattern / ● almost no dark spots on head. Size up to 500 mm SL.

Distribution. Italy: Lake Garda. Introduced in several lakes of northern Italy, Germany and New Zealand. All introductions failed.

Habitat. Lacustrine, at 100–200 m depth. Spawns at 50–300 m depths close to underwater springs.

Biology. Lacustrine, not migrating to lake tributaries. Lives up to 5 years. Males reproduce for the first time at 2 years, females at 3. Usually spawns only 1–2 years. An expended spawning season in December – February (concentrating in northern end of lake) and a shorter one in July – August (in southern part); some females may spawn in two successive seasons. Feeds mostly on zooplankton, in summer supplemented by benthic crustaceans.

Conservation status. CR A2bde. Stocks sharply declined since 1965. Overfishing, water pollution and introduction of exotic *Coregonus* and Salmonidae might be the causes. Survival may be dependent on conservation measures.

Remarks. There is no data to exclude the hypothesis that winter and summer spawners represent two separate populations or species.

Further reading. Malfer, 1927 (biology); Melotto & Alessio, 1990 (biology); Gandolfi et al., 1991: 310 (biology).

Salmo cenerinus

Common name. Northern Italian brook trout.

Diagnosis. Distinguished from other species of *Salmo* in Apennine Peninsula by: ○ parr marks absent in adults and subadults (over about 100 mm

Salmo carpio

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Salmo cf. *cenerinus*; Panaro, Po drainage, Italy; ~210 mm SL. J. Schöffmann

Salmo cettii; Anapo, Sicily, Italy; ~200 mm SL. J. Schöffmann

SL) / O parr marks vertically elongated / O caudal slightly emarginate / O body pattern not marbled / O red spots not restricted to lateral line / O black or dark brown spots present. Size up to about 800 mm SL in lakes, usually up to 400 mm SL in streams.

Distribution. From Po to Soca (where it is possibly introduced) drainages and northern slope of Apennine range (Italy, Switzerland, Slovenia).

Habitat. Streams in hilly areas, with clear, flowing and well oxygenated water (as a result of continuous stocking, often present in unsuitable habitats). Also in alpine and subalpine lakes.

Biology. Resident and lacustrine forms. Lives up to at least 8 years. Males reproduce for the first time at 2 years, females at 3. In November – February (depending on altitude and temperature) moves to smaller tributaries to spawn on gravel. Feeds on aquatic insects and invertebrates, large individuals also prey on fishes.

Conservation status. DD*.

Remarks. Genetic data show that northern Italian brook trout represents a lineage very different from those of the Atlantic and Black Sea basins, but there is no published morphological comparison, so that the diagnosis is tentative. Furthermore, *S. trutta* has been widely stocked and has probably hybridised with most native populations. The western and eastern limits of the distribution are not clear. The status of the trouts from the Adriat-

Salmo cenerinus

Salmo cettii

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Salmo sp. Corsica; Logoniello, Ascu drainage, Corsica, France; ~180 mm SL. J. Schöffmann

Salmo sp. Corsica; Corbica, Ascu drainage, Corsica, France; ~190 mm SL. J. Schöffmann

ic-Ionian slope of southern Italy has not been investigated.

Further reading. Gandolfi et al., 1991: 285 (biology; as *S. trutta*, in part).

Salmo cettii

Common name. Mediterranean trout.

Diagnosis. Distinguished from other species of *Salmo* in Mediterranean basin by: ○ 9–13 parr marks in adults / ○ caudal slightly emarginate / ○ 20–60 small ocellated spots on flank (smaller than eye), some black, some brownish red. Size up to about 400 mm SL.

Distribution. Corsica, Sardinia, Sicily, Tyrrhenian basin of Italy from Magra drainage southward.

Habitat. Streams in hilly areas; in lowland in karstic resurgences. Clear waters around 10–20°C, usually with dense subaquatic vegetation.

Biology. Spawns in January – March, on gravel bottom, in shallow water. Feeds mainly on aquatic insects.

Conservation status. NT*. Threatened by water abstraction, overfishing and stocking of non-native trouts.

Remarks. Often appears in the literature as *S. macrostigma*, a name either invalid or that can be used only for an Algerian trout, if distinct. We retain the name *S. cettii* for the trouts with parr marks of the drainages of the Tyrrhenian basin and Sicily. Recent studies, however, suggest that the trouts of Sicily (at least the surviving native populations) belong to a distinct molecular lineage otherwise found only in Morocco. This lineage is identifiable by colour pattern (usable morphological information are totally lacking), suggesting a diagnosable species. If confirmed, this lineage should retain the name *S. cettii*; the name *S. ghigii* would probably be the valid name of the others. The status of the populations from Corsica is not yet clear. Trouts retaining parr marks in adults are also present in southwestern France (southern Garonne tributaries and Adour drainages, Atlantic basin; Aude drainage, Mediterranean basin) and Iberian Peninsula (Ebro basin, Mediterranean basin). They have also been called *S. macrostigma* but apparently represent several distinct, unnamed and unstudied species.

Further reading. Gandolfi et al., 1991: 299 (biology); Delling, 2003 (systematics); Schöffmann et al., 2007 (genetics).

Salmo fibreni

Common name. Fibreno trout.

Diagnosis. Distinguished from other species of *Salmo* in Italy by: ● 7–11 large parr-marks in adults / ● 15–20 large roundish, ocellated spots

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Salmo cf. *cettii*; tributary to Posta Fibreno, Italy; ~300 mm SL. J. Schöffmann

Salmo fibreni; Lake Posta Fibreno, Italy; ~140 mm SL (posterior part of body injured). J. Schöffmann

on flank, reddish or dark brown (ocellus about eye-size). Spawns earlier and at smaller size (males at 90–100 mm SL, females at 110–120) than sympatric *S. cettii* (males at 145–160 mm SL, females at 230–250). Size up to 195 mm SL.

Distribution. Italy: Lake Posta Fibreno and tributaries.

Habitat. Lake Posta Fibreno is an elongated karstic lake with underwater springs and caves, 1.1 km long, 0.1–0.3 km wide, 0.29 km^2, 289 m above sea level, 15 m deep (average depth 2.5 m), about 10°C year-round and clear and well oxygenated water. Spawns close to underwater springs.

Biology. Lacustrine, sometimes entering lake tributaries. Spawns in December – January (local *S. cettii* population in February – March).

Conservation status. VU D2*. The entire range is included in Lago di Posta Fibreno Nature Reserve. The small lake is very vulnerable to fish introduction or accidental pollution.

Further reading. Zerunian & Gandolfi, 1990 (description); Gandolfi et al., 1991 (biology); Kottelat, 1997 (systematics).

Salmo marmoratus

Common name. Marble trout.

Diagnosis. Distinguished from other species of *Salmo* in Adriatic basin by: ● body silvery to olive-green with irregular brown lines forming a marbled pattern / ● parr marks absent in individuals larger than 60 mm SL / ○ adipose with red to orange margin at least in individuals smaller than 200 mm SL / ○ red spots restricted to lateral line, absent in some individuals and populations / ○ opercle with brownish blotches or lines /

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Salmo marmoratus; Soca, Slovenia; 203 mm SL. B. Delling

Salmo marmoratus; Soca, Slovenia; 291 mm SL. B. Delling

♀ head length 22–25 % SL / ♀ eye diameter 1.7–2.2 times in interorbital distance, 3.1–4.3 times in postorbital length (at 250–350 mm SL). Size up to at least 1200 mm SL and 50 kg, usually 250–600 mm SL.

Distribution. Adriatic basin, from Po (only northern tributaries) to Soca and Rizana drainages (Italy, Slovenia). Introduced in Tevere drainage (Italy). See below for Neretva, Skadar and Drin populations.

Habitat. Cold streams and rivers in montane and piedmont landscapes with temperature usually not rising above 15°C in summer. Spawns in gravel of rivers and streams with swift water (0.4–0.5 m/s) at moderate depth (0.6–0.8 m).

Biology. Lives up to at least 10 years. Males reproduce for the first time at 3 years, females at 4. Spawns in November – January when temperature falls below 6°C. Spawning most intensive during evening hours at new moon. It usually lasts about one month, but in some rivers it takes place only during a few days. No or only very short spawning migrations. Individuals foraging in lakes migrate to lake tributaries to spawn. Males start to occupy spawning grounds about one week before females. Eggs hatch in about 45 days. Alevins start to feed 59–63 days after spawning at 10°C. Feeds on a wide variety of aquatic and terrestrial invertebrates, becomes piscivorous when adult.

Conservation status. LC. Threatened by hybridisation with introduced *S. trutta* and *S. cenerinus*; only a few pure populations remain. Situation apparently improved with stocking of pure strains. Might return to a threatened category if conservation measures were to end. Also threatened by pollution, overfishing and river regulation.

Remarks. Molecular data suggest that populations identified as *S. marmoratus* from Neretva drainage (Bosnia-Herzegovina, Croatia) and most likely those from Lake Skadar basin and Drin to Shkumbin drainages (Montenegro, Albania, Kosovo, Macedonia) belong to another, as yet unidentified species.

Further reading. Gandolfi et al., 1991: 293 (biology); Povž et al., 1996 (biology); Delling, 2002 (morphology).

Salmo rhodanensis

Common name. Rhône trout.

Diagnosis. Distinguished from other species of

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Salmo rhodanensis; Doubs, Rhône drainage, Switzerland; 305 mm SL.

Salmo in Europe by: ● body with 4 broad black bars, behind gill opening, under dorsal base, above anal origin and at posterior extremity of caudal peduncle (bars clearly distinct in non-stressed individuals; some Balkan species may show similar bars, but only in very stressed situations; in other species only weakly marked when stressed) / ○ caudal truncate to slightly emarginate / ○ usually no red spots on body / ○ usually no red or orange dot on adipose / ○ juveniles with 9–12 vertically elongated parr marks. Size up to about 800 mm SL.

Distribution. Rhône drainage, except Lake Geneva basin (France, Switzerland). Apparently eastward to Roia drainages (France, Italy), possibly further eastward in Ligurian Sea basin.

Habitat. Rivers and streams, in clear, cold, well oxygenated water, with slow to fast current.

Biology. Spawns for the first time at 4 years. Spawns in late December, at temperatures about 4°C, on gravel or coarse sand. Feeds on invertebrates, fish, amphibians.

Conservation status. DD*. Several populations include a significant proportion of hybrids with *S. trutta* produced in aquaculture and stocked.

Remarks. The diagnostic 4 broad bars are present in populations of Dourbie (upper Tarn system, France), which is distinguished by the presence of red spots and dorsal, pelvic and anal with white anterior margin. This is possibly an introgression zone between *S. rhodanensis* and *S.* cf. *cettii*.

Further reading. Mezzera et al., 1997 (diagnosis, juveniles); Kottelat, 1997: 138 (systematics).

Balkan Peninsula

The systematics of the Balkan trouts is far from resolved. Numerous species have been recognized by earlier authors who listed characters they considered as diagnostic but usually without providing actual comparisons with other populations. The following list of species and diagnostic characters are partly the findings of recent or continuing studies, with slight nomenclatural adjustments, but a large part of the data is from the literature. Unfortunately, the published data are heterogeneous, incomplete and often contradictory and superficial, therefore the diagnoses should be considered tentative.

See above for *S. marmoratus* also known from Italy and Slovenia. A morphologically distinct species is present in Lipkovska stream (upper Vardar drainage, Macedonia, adjacent to Danube drainage), which we tentatively refer to the Danubian *S. labrax*.

Lake Ohrid, southern end, Macedonia.

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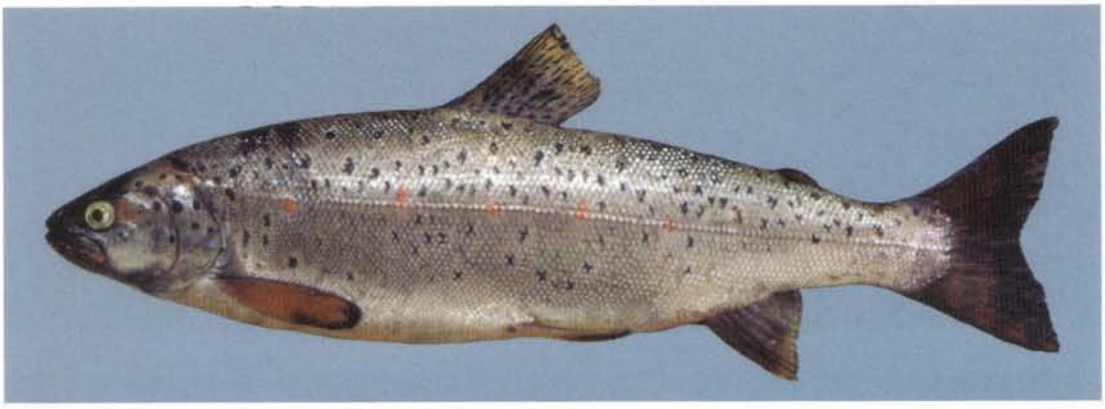

Salmo aphelios; Lake Ohrid, Macedonia; ~350 mm SL.

In the absence of material, we gave the benefit of the doubt to some species and consider them as valid, pending availability of usable material or data. **Further reading.** Delling, 2003 (systematics).

Lake Ohrid. The trouts of Lake Ohrid (347 km^2, maximum depth 289 m, average depth 164 m) are classically considered as belonging to 4 races, varieties or subspecies. They have different ecology, spawning sites and spawning seasons; they differ in osteology and reportedly in external morphology and these differences are considered inherited. Therefore, on the basis of the published information, the 4 stocks would fulfil the criteria for recognition as 4 species.

Alternatively, some authors consider that the 4 stocks are only variants of a single species, that the differences in morphology are mere adaptations to local environment and that differences in spawning season are due to some individuals maturing later. Others consider that individuals need about 18 months between consecutive spawning events and that this explains the different spawning seasons. These hypotheses are mere statements, for which we found no supporting evidences, and without information that suggests that the earlier data on inherited morphological characters and spawning seasons are erroneous. Hatchery-produced trouts have not been demonstrated to spawn successively during different seasons; further, we found no documented evidence for movements between winter and summer spawning sites. On the other hand, it is known that in Lake Garda, the endemic *S. carpio* has two spawning seasons.

Although authors have referred to "real" or "important" differences in "many characters," the published data in fact show broad overlap of all morphometric and meristic characters and only minor differences in average values. It is not possible to extract useful diagnoses from these data. Fishermen distinguish winter spawning trouts from summer spawning trouts by the colour of the flesh ("white" [pinkish], vs. orange) and its fat content. Anatomical studies show that at least *S. letnica*, *S. balcanicus* and *S. aphelios* can be diagnosed by osteological characters (*S. lumi* was not examined in that study). Pending more convincing arguments or better organised data, we have no choice but to tentatively retain the 4 species as distinct, based on life history and osteology, although we are unable to provide diagnoses based on external characters.

It might be too late to elucidate the identity and status of the different Ohrid trouts. They have been artificially produced and stocked since the 1930s, and different stocks have possibly been mixed, and movements between the lake and the spawning sites of *S. balcanicus* are no longer possible as the outlet of the lake has been obstructed by a weir, in addition to which the spawning sites have been flooded by two reservoirs. In Macedonia, fishing of Lake Ohrid trouts is banned since 2005.

Further reading. Stefanovic, 1948 (biology); Stanković, 1953: 482, 1960: 202–205 (diversity); Karaman, 1966 (systematics); Dorofeyeva et al., 1983 (osteology); Šorić, 1990: 317 (systematics); Kottelat, 1997: 131 (systematics); Sell & Spirkovski, 2005 (genetics); Sušnik et al., 2006 (genetics).

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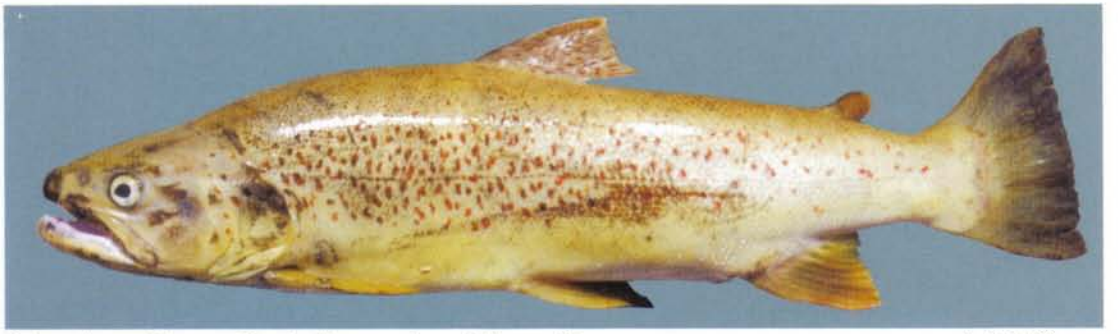
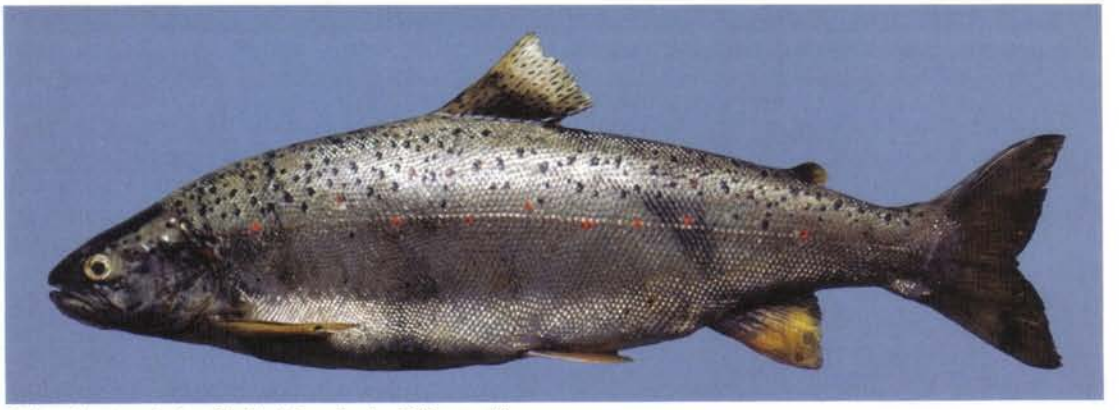


Salmo dentex; Neretva, Bosnia-Herzegovina; ~540 mm SL. J. Schöffmann



Salmo letnica; Lake Ohrid, Macedonia; 500 mm SL.

Salmo aphelios

Common names. Summer trout, letnica.
Diagnosis. See *S. letnica*. Said to be distinguished from other species of *Salmo* in Lake Ohrid by its orange flesh. Size up to at least 400 mm SL.
Distribution. Macedonia: eastern shore of Lake Ohrid.
Habitat. Lacustrine.
Biology. Spawns near sub-lacustrine springs along eastern shore of the lake, in May – July.
Conservation status. DD.
Further reading. Stefavovic, 1948 (biology; as *S. letnica aestivalis*); Kottelat, 1997: 133 (nomenclature).

Salmo balcanicus

Common names. Struga trout, kresnica.
Diagnosis. See *S. letnica*. Flesh pinkish. Size up to at least 400 mm SL.
Distribution. Northwestern shore of Lake Ohrid (Albania, Macedonia) and outlet.
Habitat. Lacustrine species entering outlet.
Biology. Spawns at and in outlet of lake in October – January.
Conservation status. DD. Potentially extinct. Original spawning sites apparently no longer accessible as the outlet of the lake has been obstructed by a weir and two reservoirs have flooded the spawning sites.
Further reading. Stefavovic, 1948 (biology); Sell & Spirkovski, 2005: 3634 (extinct).

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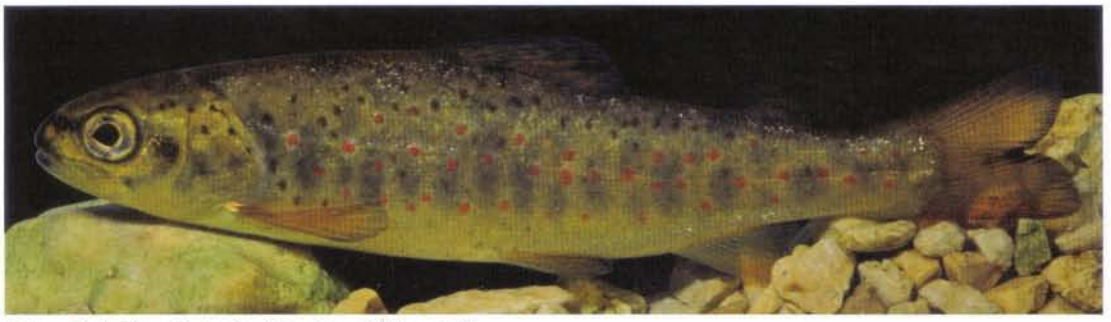

Salmo farioides; Zrmanja, Croatia; ~100 mm SL.

Salmo farioides; Neretva, Bosnia-Herzegovina; 230 mm SL. B. Delling

Salmo dentex

Common name. Zubatak.

Diagnosis. Distinguished from other species of *Salmo* in Balkan Peninsula by: ○ preanal length 77–80 % SL / ○ predorsal length 47–50 % SL / ○ interorbital distance 20–25 % HL / ○ head and body with small dark dots, especially in upper part / ○ dark red spots of different sizes, on whole flank, circled by bright pale rim. Size up to at least 620 mm SL.

Distribution. Adriatic basin, from Krka to Aoos drainages (Croatia, Bosnia-Herzegovina, Montenegro, Albania, Greece, Kosovo, Macedonia); possibly present in Alfios (Peloponnese, Greece).

Habitat. In lakes and large rivers. Spawns on gravel bottom.

Biology. Resident and lacustrine forms. In Lake Skadar basin, overwinters in deep parts of lake, moves to main tributaries in summer.

Conservation status. DD*.

Further reading. Ivanovic, 1973: 70 (biology); Delling, 2003 (morphology).

Salmo farioides

Common name. Balkan brook trout.

Diagnosis. Distinguished from other species of *Salmo* in Balkan Peninsula by: ○ preanal length 73–80 % SL / ○ predorsal length 44–50 % SL / ○ 18–21 total gill rakers / ○ interorbital distance 24–31 % HL. Size up to at least 300 mm SL.

Distribution. Streams of eastern Adriatic slope, from Zrmanja to Mornos drainages (Croatia, Bosnia-Herzegovina, Montenegro, Albania, Macedonia, Greece); *Salmo* from Alfios (Peloponnese) possibly belong to this species.

Habitat. Stretches with swift, clear, cold water, rapids, small waterfalls.

Biology. No data. Resident life history.

Conservation status. NT*.

Remarks. *S. farioides* as understood here is probably an artificial assemblages of several species. Several of the examined populations differ morphologically.

Further reading. Karaman, 1932: 2 (diagnosis); Delling, 2003 (morphology; as *S.* cf. *farioides*).

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Salmo macedonicus; Vardar drainage, Macedonia; 198 mm SL.

Salmo letnica

Common name. Pestani trout.

Diagnosis. See above discussion of Ohrid trouts. Distinguished from other species of *Salmo* in Balkan Peninsula by: ♦ lacustrine / ♦ size up to at least 600 mm SL / ♦ in large adults, head and body silvery, with black spots, especially in upper part, red spots (when present) mainly along lateral line / ♦ flesh pinkish. Size up to at least 600 mm SL.

Distribution. Macedonia: eastern shore of Lake Ohrid.

Habitat. Lacustrine. Spawns in littoral and sublittoral areas.

Biology. Spawns for the first time at 5–6 years. Spawns in January – February. Juveniles feed on zooplankton, adults feed on zooplankton and fish (mainly *Alburnus scoranza*).

Conservation status. DD.

Further reading. Stefanovic, 1948 (biology); Šorić, 1990: 314 (morphology); Kottelat, 1997 (systematics).

Salmo lumi

Common name. Lumi trout.

Diagnosis. See *S. letnica*. Published 'diagnostic' information not usable, existence doubtful. Size up to at least 380 mm SL.

Distribution. Northern and westerns shores of Lake Ohrid (Albania, Macedonia).

Habitat. Lacustrine, spawns in tributaries and at their mouth.

Biology. Spawns in December – February.

Conservation status. DD.

Remarks. Tentatively recognized as valid species (given the benefit of the doubt) in the absence of data allowing a critical decision.

Further reading. Stanković, 1953: 482 (biology).

Salmo macedonicus

Common name. Macedonian trout.

Diagnosis. Distinguished from other species of *Salmo* in Balkan Peninsula by: ♦ flank (especially anterior part) and opercle with numerous large, ocellated, dark wine-red spots, sometime blackish in middle (in Kadina basin; anterior ones covered by black pigments in Babuna and Dosnica basins) / ♦ dorsal with some weak wine-red spots / ♦ large (over 300 mm SL) individuals with 3 broad black bars on posterior half of body, distinct only when stressed. Size up to at least 400 mm SL.

Distribution. Macedonia: upper Vardar drainage (except Crna system).

Habitat. Stretches with swift water, rapids, small waterfalls.

Biology. No data. Resident life history.

Conservation status. DD.

Further reading. Karaman, 1924: 16, 1938: 133 (description).

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Salmo cf. *montenegrinus*; Neretva drainage, Bosnia-Herzegovina; ~200 mm SL.

Salmo obtusirostris; Neretva, Bosnia-Herzegovina; ~370 mm SL. J. Schöffmann

Salmo montenigrinus

Common name. Montenegro trout.

Diagnosis. Distinguished from other species of *Salmo* in Balkan Peninsula by: ○ maxilla short (26–39 % HL) but deep (11–14 % HL) / ○ 21–23 gill raker / ○ body depth 25–28 % SL / ○ 15–17 scales between base of adipose and lateral line / ○ back and upper part of head yellowish, without spots / ○ black spots small and numerous, more dense below lateral line, red spots more evenly distributed. Size up to at least 260 mm SL.

Distribution. Moraca and Neretva drainages (Bosnia-Herzegovina, Montenegro).

Habitat. Stretches with swift, clear water, small waterfalls.

Biology. Spawns in spring.

Conservation status. DD*.

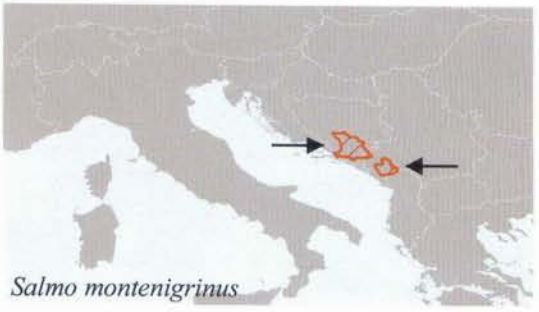
Further reading. Karaman, 1924: 16, 1938: 133 (description); Delling, 2003 (morphology).

Salmo obtusirostris

Common name. Soft-muzzled trout.

Diagnosis. Distinguished from other species of *Salmo* in Adriatic basin by: ● lips fleshy / ○ jaw teeth small or indistinct / ○ snout blunt / ○ mouth subinferior / ● lateral line scales elliptical, re-

Salmo macedonicus



Salmo montenigrinus

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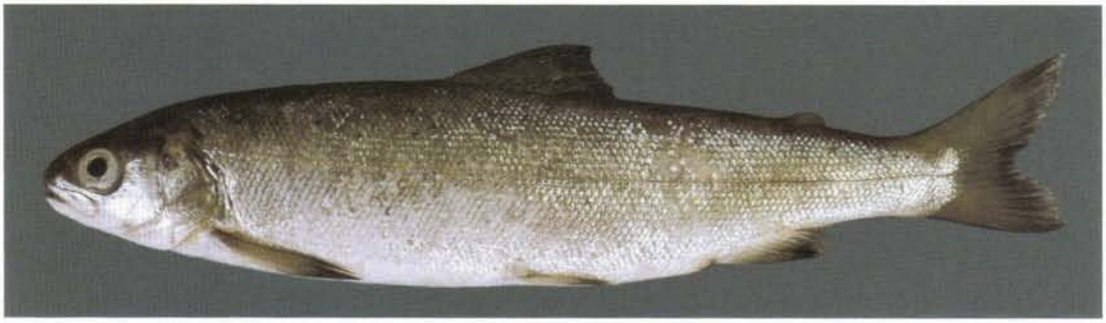

Salmo ohridanus; Lake Ohrid, Albania. P. Zupančič

duced to little more than nerve tube, smaller than scales in adjacent rows / ● lateral line scales 100–120 / ● 26–32 gill rakers. Size up to about 700 mm SL.

Distribution. Adriatic basin, Krka, Jardo, Vrljika (Croatia), Neretva (Bosnia-Herzegovina) and Zeta drainages (Montenegro). Introduced and established from Jardo to Zrnovnica drainages (Croatia) around 1960.

Habitat. Cold streams and small rivers, usually in deep, quiet places.

Biology. Gregarious, spawns in April – May at temperatures above 10°C. Feeds on invertebrates.

Conservation status. EN B2ab(v). Threatened by overfishing. Now restricted to a 300 m long stream stretch in Krka (Croatia) (if not already extirpated). A single recent record (2004) from Zeta (Montenegro). Still frequent in Neretva drainage, especially in Buna and uppermost Jardo, Vrljika and Zrnovnica streams.

Remarks. Earlier considered as a distinct genus, *Salmothymus*; see under *Salmo*. Populations of different drainages sometimes considered as distinct subspecies, but published data are insufficient to allow conclusions to be reached on their validity. Based on published data, we tentatively recognize only a single species.

Further reading. Svetovidov, 1975 (osteology); Snoj et al., 2002 (genetics); Schöffmann, 2003 (conservation status).

Salmo ohridanus

Common name. Belvica.

Diagnosis. Distinguished from other species of *Salmo* in Balkan Peninsula by: ○ 100–114 lateral line scales / ○ 11–12 scale rows between lateral line and adipose / ● usually 54–55 vertebrae (56–63 in other *Salmo* species) / ● teeth on vomer extending to posterior-most end of shaft (Fig. 73a) / ○ 2 supraorbitals / ○ snout blunt, its length about equal to eye diameter / ○ body plain yellowish silvery or with a few small, x-shaped pinkish dots / ○ 18–22 gill rakers / ○ 25–59 pyloric caeca. Size up to about 350 mm SL.

Distribution. Lake Ohrid (Albania, Macedonia).

Habitat. Lacustrine, from surface to about 20 m depth in summer, near shores in winter.

Biology. Spawns in December – February, along shores. Eggs hatch in 45–55 days at 10°C. Forms schools.

Conservation status. VU D2, threatened by intentional hybridisation going on for 50 years.

Remarks. Earlier considered as a distinct genus, *Acantholingua*; see under *Salmo*.

Further reading. Steindachner, 1892: 379 (description); Hadžišče, 1961 (morphology); Svetovidov, 1975 (osteology); Stearley & Smith, 1993 (systematics); Snoj et al., 2002 (genetics); Sušnik et al., 2006 (genetics).

Salmo pelagonicus

Common name. Pelagos trout.

Diagnosis. Distinguished from other species of

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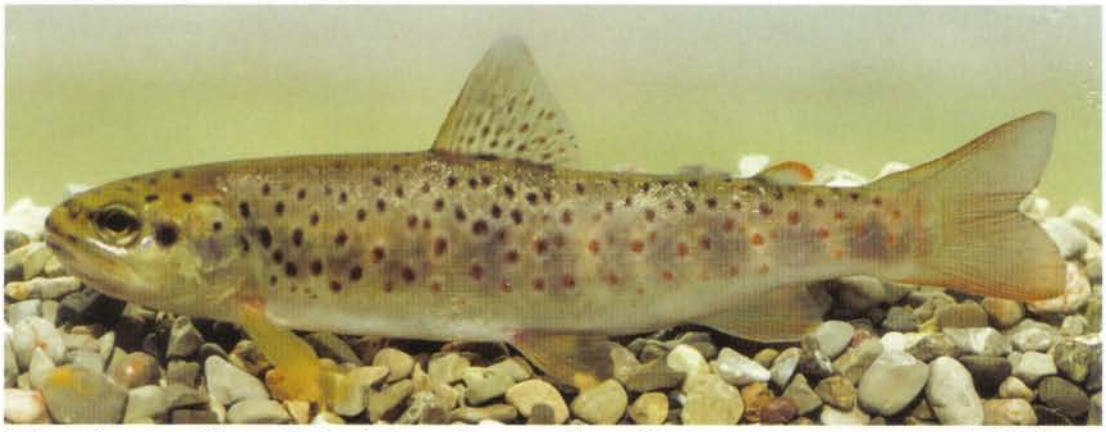

Salmo pelagonicus; Skopos, Vardar drainage, Greece; ~150 mm SL. J. Schöffmann

Salmo pelagonicus; Aliakmon drainage, Greece; 191 mm SL. B. Delling

Salmo in Balkan Peninsula by: ❍ body depth 24–28 % SL / ❍ upper jaw extending beyond posterior margin of eye / ❍ black spots mainly on upper half of flank, pinkish to orange spots along lateral line and lower half of flank, black spots more numerous than orange ones only in anterior part of flank. Size up to at least 300 mm SL.

Distribution. Lower Vardar (Crna system) and upper Aliakmon drainages (Macedonia, Greece); populations from Stumica drainage possibly represent a distinct species.

Habitat. Mountain streams.

Biology. No data. Resident life history.

Conservation status. VU B1ab(v)*.

Further reading. Karaman, 1938: 133 (description).

Salmo peristericus

Common name. Prespa trout.

Diagnosis. Distinguished from other species of *Salmo* in Balkan Peninsula by: ❍ small black spot on opercle and upper third of flank, ocellated red spots on whole flank / ❍ body depth 19–23 % SL in SL / ❍ 16–18 gill rakers / ❍ preanal length 72–75 % SL. Size up to at least 350 mm SL.

Distribution. Lakes Prespa basin (Greece, Macedonia, Albania).

Habitat. Streams. Believed to have originally been

Salmo pelagonicus

Salmo peristericus

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Salmo peristericus; Lake Prespa, Greece; 210 mm SL.

Salmo taleri; Zeta, Montenegro; ~100 mm SL. D. Marić

a lacustrine species entering streams to spawn, then returning to lake. Habitat modifications and water abstraction have interrupted the lower course of most streams and distribution is restricted to headwaters, possibly to two streams only.
Biology. Spawns in November.
Conservation status. EN B1ab(iii) + 2ab(iii).
Remarks. Large individuals (up to about 600 mm SL) with lacustrine phenotype occasionally observed in the lake apparently belong to *S. letnica*, which was earlier stocked in Macedonia.
Further reading. Catsadorakis et al., 1996: 15 (migrations); Delling, 2003 (morphology).

Salmo taleri

Common name. Zeta trout.
Diagnosis. Distinguished from other species of *Salmo* in Balkan Peninsula by: ○ few black spots on flank and side of head / ○ red spot dark, wine-red / ○ body depth 23–29 % SL / ○ preanal length 75–79 % SL / ○ predorsal length 47–49 % SL / ○ interorbital distance 29–32 % SL. Size up to at least 300 mm SL.

Distribution. Montenegro: upper Zeta river, Moraca drainage.
Habitat. Mountain streams.
Biology. No data. Resident life history.
Conservation status. DD*.
Further reading. Karaman, 1932: 2 (diagnosis); Delling, 2003 (morphology; as *S.* cf. *farioides*).

Salmo sp. Louros

Common name. Louros trout.
Diagnosis. Distinguished from other species of *Salmo* in Balkan Peninsula by: ○ small black spots on opercle and upper third of flank, ocellated red spots on whole flank / ○ body depth 26–30 % SL / ○ 18–21 gill rakers / ○ preanal length 73–77 % SL / ○ length of maxilla 37–41 % HL / ○ interorbital distance 30–32 % HL / ○ length of caudal peduncle 18–19 % SL. Size up to at least 217 mm SL.
Distribution. Greece: Louros drainage.
Habitat. Stream with clear, cold water.
Biology. No data. Resident life history.
Conservation status. EN B1ab(v)*, probably critically threatened by habitat modification and poaching.

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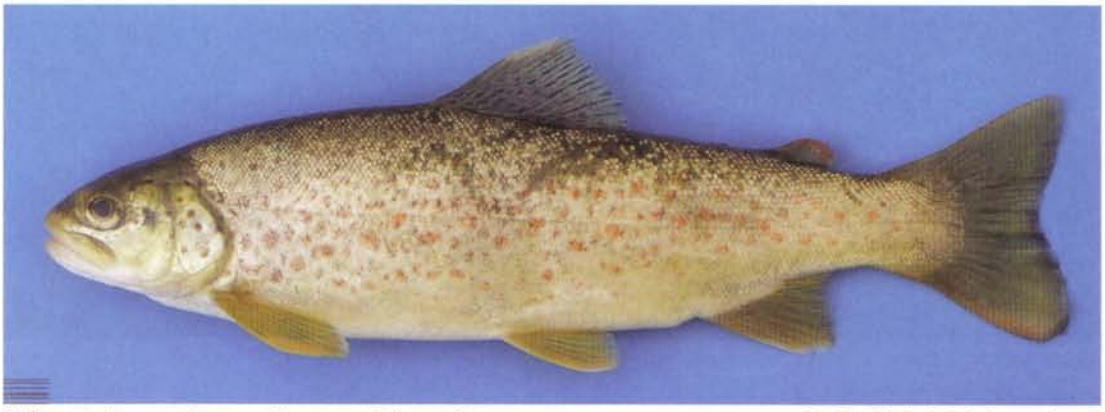


Salmo sp. Louros; Louros, Greece; ~200 mm SL. R. Barbieri & M. Stoumboudi

Salmo ciscaucasicus; upper Samur drainage, Russia; ~200 mm SL. A. Naseka

Further reading. Delling, 2003: IV, 22 (description).

Black and Caspian Sea basins

Salmo ciscaucasicus

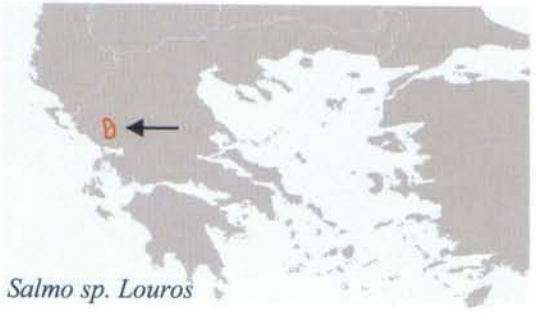
Common name. Terek trout.

Diagnosis. Distinguished from *S. ezenami*, only other *Salmo* in European Caspian basin by: ● maxilla reaching posterior margin of eye / ● gill rakers pointed, tips never club-shaped. Distinguished from *S. caspius*, restricted to southern Caspian basin by: ● body depth about 15–20 % SL (vs. 21–26) / ○ head depth about 59–65 % HL (vs. 68–75) / ○ inter orbital distance about 30–42 % HL (vs. 37–48). Size up to 1300 mm SL.

Distribution. Coastal zone of western Caspian Sea, drainages from northern Azerbaijan to Volga and Ural. Main spawning river was Terek.

Habitat. At sea, along western coast at depths of up to 50 m. Migrates to hill streams. Resident part of populations in streams and uppermost reaches with fast current, cold clear water and stone or gravel bottom. Spawning sites usually located in upper reaches of rivers with fast current.

Biology. Anadromous, lacustrine and resident forms. Spawns for the first time at 3–5 years, females 1 year later than males. Spawns in October – December. Prior to the construction of dams and river regulation, there were two migration runs, the first in summer-autumn, peaking in October, with the adults spawning the same autumn and



Salmo sp. Louros

Salmo ciscaucasicus

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Salmo labrax; Crimea, Ukraine; ~300 mm SL.

returning to sea in December; the second in late autumn-winter, peaking in December – February, with the adults spawning in autumn of following year after about 10–12 months in river. Eggs hatch in 6–8 weeks. Anadromous individuals in Terek drainage probably spawned once in life, but some females from other populations up to 4 times. Parrs spend 2–4, sometimes more, years in river, then migrate to sea. Commonly spends up to 4 years at sea before migrating back to river. Parrs and resident adults feed on a wide variety of aquatic and terrestrial invertebrates. Anadromous and large lacustrine individuals feed mainly on fish, also on large crustaceans. Anadromous individuals feed while in rivers.

Conservation status. LC*. Due to damming, migrating juveniles no longer reach the sea and returning adults no longer reach the spawning sites. The survival of the species relies only on resident populations. No reliable data on results of stocking (if fish farms still operate!) since Soviet times. Some authors consider that the resident and anadromous populations are not conspecific, and that *S. ciscaucasicus* is made only of the anadromous populations. In this case, the anadromous species *S. ciscaucasicus* is possibly extinct.

Remarks. The published data do not allow to distinguish resident *S. ciscaucasicus* of headwaters of Caspian basin from resident *S. trutta* and *S. labrax* of the Atlantic, Baltic and Black Sea basins, based on external characters. In northern Volga and Ural drainages, *S. trutta* and hybrids with *S. ciscaucasicus* might be present.

Further reading. Berg, 1948: 242 (biology, morphology, distribution; as *S. t. caspius*, in part); Dorofeyeva, 1967: 15 (morphology, taxonomy); Belyaeva et al., 1989: 112 (biology, fisheries); Danilov-Danilyan, 2001: 269 (conservation).

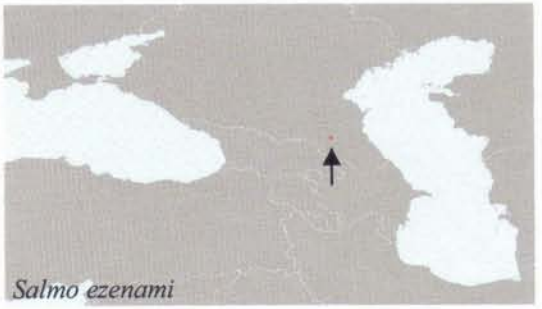
Salmo ezenami

Common name. Kezenoi-am trout.

Diagnosis. Distinguished from other species of *Salmo* in Caspian Sea basin by: ● 16–21 short and broad gill rakers, without denticles; in large individuals sometimes slightly expanded at tip / ● maxilla not reaching posterior margin of eye / ● bright coloration: 10–30 relatively large (6–7 mm in diameter) carmine red spots above lateral line, small black spots on back, red spots on dorsal, upper caudal lobe, and adipose. Size up to 1130 mm SL and 17 kg.

Distribution. Russia: Lake Kezenoi-am (formerly Eizenam) (Daghestan) in northern Caucasus. In 1963, introduced in Lake Mochokh (Daghestan), probably established.

Habitat. Lake Kezenoi-am is a mountain lake at 1870 m above sea level, 2.4 km^2, with a maximum depth of 74 m, temperatures about 5°C below 20 m and 5–18°C in upper layers in summer, covered by ice in winter, high oxygen concentrations down to bottom year-round and low plankton density. Spawns in lake, close to underwater



Salmo ezenami

Salmo labrax

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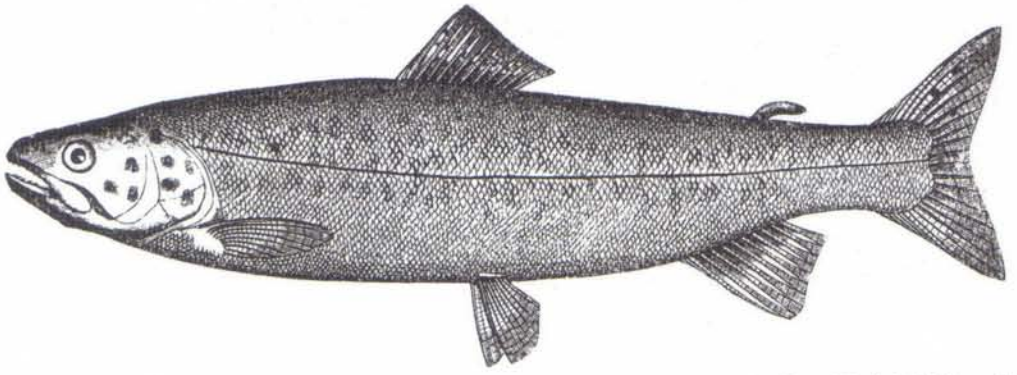

Salmo schiefermuelleri; Austria. (from Heckel & Kner, 1858)

springs; large-sized individuals probably migrate to tributaries. Prior to the introduction of *Gobio holurus* and *Squalius cephalus*, *S. ezenami* was the only fish in the lake.

Biology. Lacustrine, migrates to tributaries. Two groups of individuals are known: small-size (adults 160–260 mm SL, 200–350 g) and large-size (adults 380–1130 mm SL, over 1 kg). Males reproduce for the first time at 2 years, females at 3. Spawning period extends over almost entire year. Young juveniles feed mostly on gammarids, chironomid larvae; larger juveniles and adults feed on molluscs, benthic invertebrates and fry; largest individuals are mostly piscivorous, especially since the introduction of *Gobio holurus*.

Conservation status. CR B1ab(iii,v) + 2ab(iii,v)*. Highly impacted by introduction of *Squalius cephalus*, which feeds on its fry.

Further reading. Berg, 1948: 253 (description); Saidov & Magomedov, 1989: 45 (morphology, biology); Danilov-Danilyan, 2001: 271 (conservation).

Salmo labrax

Common name. Black Sea trout.

Diagnosis. Distinguished from other species of *Salmo* in Black Sea basin by: ● caudal only slightly emarginate / ○ 16–18 (usually 18) gill rakers (vs. 13–18, usually 16, in *S. trutta*) / ● eggs yellow or orange, about 5 mm in diameter. Size up to about 800 mm SL.

Distribution. Rivers draining to Black Sea; Lipkovska stream in upper Vardar drainage (Macedonia).

Habitat. At sea, along coasts at depths of up to 50 m. Migrates to hill streams. Resident part of populations in streams and uppermost reaches with fast current, cold clear water and stone or gravel bottom. Spawns in upper reaches with fast current.

Biology. Anadromous, lacustrine and resident forms. Spawns in October – January. Parrs spend 2–4 years in rivers and streams, then smoltify and migrate to sea or mature in freshwater. Spends 2–4 years at sea. Some anadromous individuals return to rivers in April – May, where they spend the summer. Others anadromous individuals start migrate shortly before spawning. Eggs hatch in 6–8 weeks. Parrs and resident adults feed on a wide variety of aquatic and terrestrial invertebrates. Anadromous and large lacustrine individuals feed mainly on fish and large crustaceans. Anadromous individuals feed while in rivers.

Conservation status. LC*, anadromous individuals very rare in Europe, most abundant in southern Caucasus and Turkey. Because of damming, most returning adults are unable to reach spawning sites.

Remarks. Genetic data show that resident trouts from the northern Black Sea basin represent a lineage very different from those of the Atlantic, Mediterranean and Caspian basins, but there is no published morphological comparison. Presently, we recognise a single species of *Salmo* in the northern Black Sea basin (in addition to the extinct *S. schiefermuelleri*). A population from upper Vardar (Lipkovska) is tentatively referred to *S. labrax*; it is superficially distinguished from all Balkan species by its very slightly emarginate caudal. In upper Danube, *S. trutta* is present and hybrid populations are or might be present in lower Danube, Dniestr, Dniepr and Don.

Further reading. Berg, 1948: 239 (biology); Salmanova & Dorofeyeva, 2001 (morphology); Bernatchez, 2001 (genetics).

Salmo 'schiefermuelleri'

Common name. Mayforelle.

Diagnosis. Distinguished from other species of *Salmo* in Danubian subalpine lakes by: ○ snout

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Zrmanja, Croatia; habitat of *Salmo farioides*, *Barbus plebejus*, *Phoxinus lumaireul* and *Cottus gobio*.

blunt / O body silvery, red spots on flank, blackish on back, with x-shaped or angular black spots on upper ⅔ of flank / ● eggs white, about 2 mm in diameter / O caudal fin deeply emarginate. Size up to about 700 mm SL.

Distribution. Austria: subalpine lakes in Danube drainage (Attersee, Traunsee, Fuschlersee). The same or similar species were apparently recorded in subalpine lakes in Switzerland (e.g. Vierwaldstätter [Rhine drainage]).

Habitat. Lacustrine, in deep water. Spawns along shores.

Biology. Lacustrine species, not reported to migrate to tributaries. Only caught in May (hence the vernacular name) when it comes in shallow waters, presumably to spawn. Eggs white, reportedly about 2 mm in diameter, possibly not ripe. Feeds on fishes.

Conservation status. Extinct*.

Salmo schiefermuelleri

Remarks. Ancient literature records the presence of deepwater trouts in several subalpine lakes of Austria, Germany and Switzerland. Some records are ambiguous and probably refer to lacustrine forms of *S. trutta*. Others are more detailed and indicate that different stocks existed. There is no indication whether and which of these population survive; some may still be extant, but they do not seem to have received attention. The few available life history information on *S. schiefermuelleri* support its status as a distinct species. The name mayforelle is still used locally, but not for the original species.

The 'schwebforelle' of Lake Vierwaldstätter (Switzerland) has a somewhat similar appearance but is unlikely to belong to the same lineage as *S. schiefermuelleri* as they occur in different drainages. Other populations known from some Alpine lakes, exhibit distinctive phenotypes and it is still unclear whether or not they are reproductively isolated. One such case is the Engadine trout (Lakes St. Moritz and Silsersee, Switzerland, Danube drainage), which has a distinctive morphology and colour pattern.

Further reading. Heckel, 1851: 287 (biology, diagnosis); Heckel & Kner, 1858: 261 (description, biology); Steinmann, 1944 (biology, Vierwaldstättersee, Silsersee); Kottelat, 1997: 133, 140 (systematics); Kottelat & Freyhof, 2007b (nomenclature).

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Salvelinus

The systematics of the genus *Salvelinus* (charrs) is still confused. By the turn of the 20th century several species were recognized in European waters. It was then observed that there is much variability in morphology, coloration and colour pattern between various, adjacent populations. The sympatric presence of several stocks differing in morphology, coloration, feeding habits, spawning sites and seasons was observed in several lakes. For the last 50 years, these stocks have been treated as morphs of a single species widespread throughout the Palaearctic and Nearctic areas. Some of the stocks are merely different growth phases of the same species. True polymorphism (except for sexual dimorphism) (see Box) has not been demonstrated within any population. On the reverse, sexual isolation and the genetic basis of the morphological and ecological differences has been documented, and this demonstrates that those

Polymorphism, ecotypes, growth phases

A polymorphic species is a species whose members exhibit different morphologies. Problems arise from the use of the word polymorphism for a variety of phenomena, which have little in common, for example:

1) individuals of a species may exhibit different appearances [morphs], which will be retained during the entire life of a given individual; example: the blue and yellow morphs of several cichlids;

2) a given individual may display (obligatorily or facultatively, successively or not) different appearances during its life; examples: growth phases (from larvae to fry to juvenile to adult fish), environmentally induced changes in morphology, stunting;

3) sexual polymorphism;

4) life-history forms of a species; example: resident, lake and sea forms of *Salmo trutta*.

It is important to distinguish these various phenomena. To be sound, a comparison of polymorphism in different groups of fishes can only be made if the different cases belong in the same category; that is, the comparison of 'polymorphism' in some cichlids with 'polymorphism' in some salmonids is questionable if it actually is a comparison of morphs of single species, versus successive phases of a species, or alternative life history forms, or interspecific differences.

Strictly, only category 1 constitutes polymorphism. Environmentally induced different morphologies that are (partly) reversible, belong to category 2 and are not treated as true polymorphism; they also are not ecotypes, which have a genetic basis.

Morphs of a single species occur in sympatry; they are genetically determined but do not form separate reproductive units. Different populations of a species may have different combinations of the known morphs of the species. Each individual of a species has to belong to one or another morph. There are normally no intermediates between morphs.

While the cross of two morphs of the same species, or of two individuals of the same morph, produces offspring displaying one or several of the morphs of the species, the cross of two species will produce hybrids, usually with a more or less intermediate morphology.

Environmental alterations may lead to the local 'extinction' of a life history form, but it reappears if the conditions revert to a suitable level. For example, the 'sea-trout' was extirpated in many areas of Central Europe due to heavy pollution during the 1960–80s. After improvement of the water quality, this life-history form reappeared. On the reverse, deep-water *Coregonus* and *Salvelinus* of central European lakes disappeared following deep-water pollution events. If they were life-history forms, they would have reappeared with the improvement of this habitat; the fact that they did not reappear demonstrates that they were species and not form of a species.

In the literature, the term 'ecotype' is frequently applied indiscriminately to any kind of difference more or less related with environment, without linking it to a clear definition and this lead to a great confusion. In the original definition (in botany), ecotypes are populations of the same species that occur in distinct habitats, are distinguished from each other by morphological and/or physiological characterisitics and are genetically differentiated. The word 'ecotype' is now widely (and erroneously) used to refer to sympatric 'populations', more or less distinct, and/or 'not yet a species'. Because of this confusion, the word is not used here.

(A *polymorphic* species should not be confused with a *polytypic* species, which, under the now abandoned Biological Species Concept, was an assemblage of related and allopatric species).

Further reading. Wimberger, 1994; Wiens, 1999.

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sympatric stocks that are not growth phases are distinct species.

We insist that the following is not a revision of the genus but a taxonomist's evaluation of the data (published or not) available to us. Even if very different from the proclaimed "accepted" system used by geneticists and fisheries biologists, because of the lack of key information and material, we have been very conservative in the number of species we recognize. While the diagnosis and identification of the sympatric species is relatively straightforward, it is more difficult to establish affinities, status and identity of allopatric populations or species. Some of the species are restricted to a single lake, while others occur over relatively large areas. In the case of sympatric species, there is generally one that occurs across a wide range while the other(s) is(are) endemic to a single lake or a group of closely connected lakes. It is not yet known if these sympatric species result from sympatric speciation (that is they are derived from a single ancestor, which invaded the lake and the sympatric species evolved in the lake) or if they are the result of invasion of the lake by two or more species. There is probably not a general explanation, which would apply for all sympatric complexes. It is likely that in some lakes, the species originated by sympatric evolution and that in others they originated by multiple invasions. In lakes with three species, it might also be that both mechanisms are involved.

The available data enables to distinguish species within some general areas (Alpine lakes, British Isles). For some other areas (Scandinavia), despite extensive fisheries data there is too little data usable in a taxonomic context to decide whether one or more species is present. It is possible that one or more of the species recognized here from the northern British Isles also occurs in Scandinavia.

The list of species below is tentative. Much more work is still needed to understand intraspecific variability and to document the distribution of the various species. Contrary to a frequent misconception, it is not so much genetic and other data requiring sophisticated technologies, which are missing, but basic concepts, training in morphology, and good eyes, all of which traits are not much favoured by present-day biology and curricula.

When kept in cages or in captivity, most charrs tend to change shape and appearance. These individuals are not usable for systematic analysis and no conclusion can be drawn from these morphological changes.

In the diagnoses below, colour information usually refers to male breeding coloration. In most species, females, small males and non breeding individuals are less brilliantly coloured. Furthermore, the diagnoses below apply to a 'typical' breeding fish, but there is much individual variation. Snout shape also shows variability: the snout is usually more pointed in adult males than in juveniles and females.

Further reading. Kottelat, 1997: 144 (systematics, nomenclature, concepts); Gislason et al., 1999 (genetics); Alexander & Adams, 2000 (variability, populations of Scotland and Ireland); Wilson et al., 2004 (genetics).

Scandinavia and Russia

Several species of *Salvelinus* are recognized in Scandinavia, and include several cases of sympatry. Despite the large amount of published data on fisheries and other aspects of biology, very little of these data can be integrated in a taxonomic analysis because the populations are nowhere characterised by explicit, descriptive features. Translocation and stocking has possibly also contributed to the confusion.

Pending the availability of data to resolve the taxonomy of the various populations, a pragmatic way to handle their diversity is needed. It would not be logical to treat as conspecific the sympatric stocks known to be reproductively isolated. Here, stocks with the 'normal' *S. alpinus* habitus are tentatively (and somewhat arbitrarily) considered as conspecific. In cases where sympatric stocks show reproductive isolation and are diagnosable, they are treated as distinct species. The published data facilitate the recognition of only five Scandinavian species, but clearly this is an underestimate of the actual diversity.

There is a variety of works on Russian *Salvelinus* species, with a variety of contradictory opinions and theories.

Salvelinus alpinus

Common name. Arctic charr.

Diagnosis. Distinguished from other species of *Salvelinus* in Scandinavia and European Russia by: ○ maxilla not reaching, reaching to or only slightly beyond vertical through posterior margin of eye / ○ length of maxilla about 7–9 % SL / ○ length of lower jaw about 11–14 % SL / ○ body fusiform, depth about 16–20 % SL / ○ overall coloration outside spawning season pale, commonly light grey, greenish grey or grey above and silvery white or pale pink below / ○ spots pale pink or white / ○ lips grey / ○ fins usually grey or pale pink, lower margin of caudal white, anterior mar-

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Salvelinus alpinus; Halselva, Norway; anadromous population, ~400 mm SL. S. T. Nilsen

gin of pectoral, pelvic and anal white. Size up to about 1100 mm SL.

Distribution. Iceland, Scandinavia, northern Russia [absent in rivers draining to Baltic and White Seas], Jan Mayen, Spitzberg, Kolguev, Bear and New Zemblia islands, northern Siberia, Alaska, Canada and Greenland; 'real' *S. alpinus* might be restricted to Europe and Greenland. Despite its scientific name, does not occur in the Alps.

Habitat. Mainly lacustrine. Estuaries, rivers and lakes with cold, clear water. At sea, along coasts. Usually spawns on pebble to stone bottom in lakes. Riverine stocks spawn in rivers with slow current (0.2–0.8 m/s). Some riverine anadromous stocks in Norway spawn every year in fast-flowing waters of riffles.

Biology. In large lakes, sympatric with *S. lepechini*. Most populations differ in details of mode of life, migration, growth, reproduction, food. The following information apply to the species as a whole but do not apply exactly to a particular populations, which normally would have much less variable characteristics. Populations north of about 65°N are anadromous. Juveniles spend their first 1–9 years in freshwater then move to the sea where they spend the short Arctic summer, returning to overwinter in frozen lakes or rivers. Some authors report that there is apparently no strict homing and that marine-feeding individuals become more opportunistic with age as to the choice of the river and lake they return to; in other areas, other authors consider that there is a strict homing. At sea, they remain in coastal areas; the longest documented marine migration is 940 km. Landlocked populations migrate within river drainage or are sedentary, lacustrine. Dwarf stocks are known in some Finnish lakes and upper stretches of rivers, characterised by a very slow growth rate; mature adults reach only 300–350 mm SL and 250–300 g (2000–5000 g in partly sympatric 'normal' lacustrine stocks).

Lives up to a maximum of 32 years (usually up to 15). Anadromous individuals spawn for the first time at 4–10 years, lacustrine ones at 2–5; some individuals spawn only every 3–4 years. Anadromous stocks grow much faster than lacustrine and riverine ones. Usually spawns in October – December; some populations spawn in spring, summer or winter. Prefers pebbles where males build nests 2–3 m in diameter. Usually, males are territorial and may spawn with several females. After spawning, some stocks return to sea, others remain 1–3 years in freshwater before returning to sea. In freshwater, feeds on benthos, plankton and small fish. At sea, feeds mainly on fish; anadromous individuals feed little in freshwater and not at all during migrations.

Conservation status. LC. Several populations have significantly declined.

Remarks. Anadromous, semi-anadromous, lacustrine, fluviatile-lacustrine and dwarf stocks are known, sometimes in sympatry. For most of them, detailed data are not available. Once available they are likely to show that several species are involved,

Salvelinus alpinus

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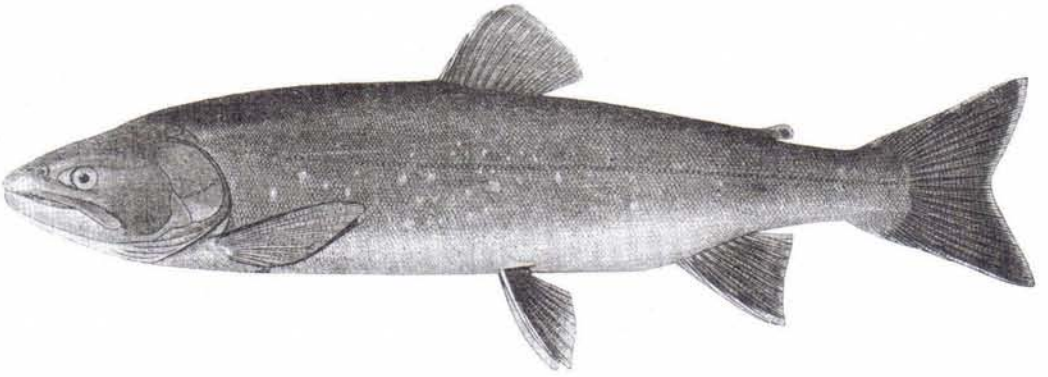

Salvelinus lepechini; Lake Ladoga, Russia; 570 mm SL. (from Berg, 1932)

whose identity is presently masked by unclear species definitions.

If Alpine and northern European populations are considered conspecific as still asserted by numerous authors, then the name *S. alpinus* is not available for the present species but should be replaced by *S. umbla*, as required by the International Code of Zoological Nomenclature.

Further reading. Balon, 1980 (biology); Kaukoranta et al., 2000: 21 (biology, distribution); Brunner et al., 2001 (genetics).

Salvelinus lepechini

Common name. Palia.

Diagnosis. Distinguished from other species of *Salvelinus* in Scandinavia and Russia by: ● maxilla clearly reaching beyond posterior margin of eye in adults / ○ length of maxilla about 9–11 % SL / ○ length of lower jaw about 13–20 % SL / ○ body depth about 18–24 % SL / ○ overall coloration outside spawning season dark, commonly greyish green above and bright orange or yellow on belly / ○ spots usually bright orange / ○ lips usually yellow, orange or pink (black in Lake Segozero) / ○ pectoral, pelvic and anal usually greyish red or orange, caudal with red or orange posterior edge and white or black lower margin. Size up to about 750 mm SL.

Distribution. Lakes in Sweden, Norway, southern Finland and northern Russia (Kola Peninsula, northern Karelia, including Lakes Ladoga and Onega).

Habitat. Large deep lakes, very rarely in rivers. Benthic. Spawns in lakes, in shallow water along sand-pebble shores.

Biology. In larger lakes (Ladoga, Onega), two forms: one in relatively shallow waters, about 30–50 m deep, the other one at 70–150 m. Both forms feed on fish, amphipods, molluscs, insects and gammarids. Growth is slow. Spawns for the first time at 4–6 years, spawns once every 2–3 years. Spawns in August – October.

Conservation status. LC*. Rare, true status unknown. Taxonomic status uncertain.

Further reading. Savvaitova, 1989: 21 (Kola Peninsula); Vasilieva, 1981 (morphology).

Salvelinus salvelinoinsularis

Common name. Bear Island charr.

Diagnosis. Distinguished from sympatric, non-anadromous *S. salvelinus* population by: ● maximum size 170 mm SL (vs. 530), spawns for the first time at 110 mm SL (vs. 280) / ○ 30–42 pyloric caeca (vs. 39–52) / ○ 22–26 gill rakers (vs. 24–27) / ● in mature individuals, belly drab bronze greyish (vs. bright yellow to carmine) / ○ mature individuals often with parr marks (vs. without). Size up to 170 mm SL.

Salvelinus lepechini

Salvelinus salvelinoinsularis

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Salvelinus alpinus; ~300 mm SL (above); *Salvelinus* sp. Båtsvatn; ~90 mm SL (below); in sympatry in Lake Båtsvatn, Norway. A. Klemetsen

Distribution. Bear Island (74°25'N 19°00'E).
Habitat. Shallow lakes.
Biology. Non-anadromous. Lives up to 16 years. Spawns for the first time at 6 years. Feeds on benthic invertebrates.
Conservation status. VU D2*.
Further reading. Klemetsen et al., 1985 (biology); Kottelat & Freyhof, 2007b (nomenclature).

Salvelinus sp. Båtsvatn

Common name. Båtsvatn charr.
Diagnosis. Distinguished from sympatric, non-anadromous *S. salvelinus* population by: ● maximum size 230 mm SL (vs. 550), spawns for the first time at 100 mm SL (vs. 260) / ● body very dark, belly yellowish grey (vs. body silvery, belly bright red to orange) / ○ eye diameter "probably greater". Size up to about 200 mm SL.
Distribution. Båtsvatn, a reservoir created in 1973, in northern Norway (about 68°N). The reservoir flooded three lakes, which were connected by short river stretches. Båtsvatn is 12 km long, 18 km^2, maximum depth 40 m, covered by ice for 8–9 months a year.
Habitat. Lacustrine, in littoral zones.
Biology. Spawns in August – September, in shallows, over gravel. Feeds mainly on benthic invertebrates.
Conservation status. VU D2*.
Further reading. Klemetsen & Grotnes, 1975 (biology), 1980 (genetics).

Salvelinus sp. Fjellfrøsvatn

Common name. Fjellfrøsvatn charr.
Diagnosis. Distinguished from sympatric, non anadromous *S. alpinus* stock by: ● maximum size 130 mm SL (vs. 320), spawns for the first time at 70 mm SL (vs. 200) / ● spawns in February – March in deep water (vs. September along littoral) / ● body and fins plain pale yellow in adults and juveniles (vs. typical *S. alpinus* pattern, with red to orange belly, white edge on paired fins and parr marks in juveniles). Size up to 130 mm SL.
Distribution. Fjellfrøsvatn, an oligotrophic subarctic lake on a tributary of River Målslev (69°N), Tromsø County, northern Norway.

Salvelinus sp. Batsvatn

Salvelinus sp. Fjellfrosvatn

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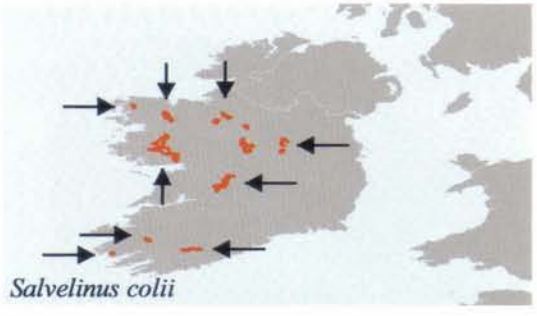
Salvelinus alpinus; ~220 mm SL; *Salvelinus* sp. Fjellfrøsvatn, ~90 mm SL; in sympatry in Fjellfrøsvatn, Norway. A. Klemetsen

Habitat. Lacustrine, below 20 m depth. The lake is oligotrophic, 6 km^2, maximum depth 80 m, flat and muddy bottom in deeper part, covered by snow and ice from November – December to May – June.
Biology. Spawns for the first time at 70 mm SL. Spawns in late February – early March. Feeds on benthic invertebrates.
Conservation status. VU D2.
Further reading. Klemetsen et al., 1997 (biology), 2002 (biology).



Salvelinus colii

British Isles and Faroe Islands

Up to 16 species of *Salvelinus* have been recognized from the British Isles and one from the Faroes. Not all are recognized as valid here, but the published data suggests that most of them are distinct species. Several other populations are known, which apparently represent additional, still unnamed species, and more probably await investigation. There are more lakes known to be inhabited by *Salvelinus* species, but in the absence of information these stocks cannot be identified to species. Unfortunately there are very few studies describing individual populations. Most recent studies (morphological and genetic) are organised in ways that make it impossible to extract data usable in a taxonomic context. Frequently, although they demonstrate by a variety of mathematical models that populations from different lakes are distinguishable, the data on which these calculations are based are not provided.
Further reading. Alexander & Adams, 2000 (diversity); Wilson et al., 2004 (genetics); Wheeler et al., 2004 (distribution).

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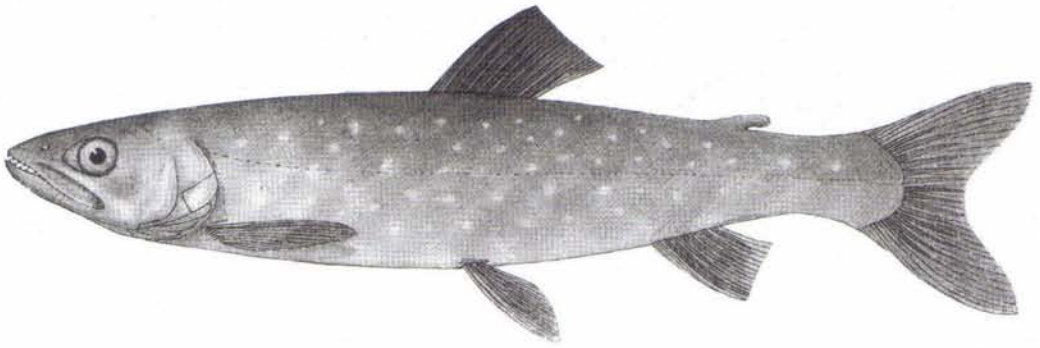


Salvelinus colii; Lough Finn, Ireland: ~200 mm SL. (from Regan, 1911)

Salvelinus colii

Common name. Cole's charr.

Diagnosis. Distinguished from other species of *Salvelinus* in Ireland by: ○ body depth 20–25 % SL / ○ snout conical, lower jaw not included in upper one / ○ length of pectoral 0.5–0.7 times in distance from its origin to pelvic origin / ○ small to indistinct spots on lower flank, whitish to red or orange. Size up to about 300 mm SL.

Distribution. Ireland: several lakes draining westward, in Kerry, Clare, Galway, Mayo, Donegal and Westmeath Counties.

Habitat. Lacustrine.

Biology. Spawns in November – December. Feeds on benthic and planktonic invertebrates.

Conservation status. NT*.

Remarks. We treat *S. scharffi* and *S. trevelyani* as synonyms.

Further reading. Regan, 1908a: 230, 1911: 102 (description); Alexander & Adams, 2000: 86 (coloration); Igoe et al., 2003 (distribution); Doherty & McCarthy, 2004 (morphology).

Salvelinus faroensis

Common name. Faroe charr.

Diagnosis. Distinguished from other species of *Salvelinus* in area by: ○ body depth 18–19 % SL / ○ snout blunt / ○ mouth subterminal, lower jaw shorter than upper / ○ maxilla reaching posterior margin of eye / ○ eye large, about 4 times in HL /

Salvelinus faroensis; Lake Leynavatn, Faroes; ~150 mm SL. H. J. Malmquist

○ belly red in males, sides probably bluish brown, without light spots / ○ pectoral, pelvic and anal red, with white anterior margin in male, "dirty yellow" in female. Size up to about 200 mm SL (to 350 mm SL in non-natural conditions).

Distribution. Faroe Islands: Lake Leynavatn, on Streymoy Island.

Habitat. Deep lake.

Biology. Lives up to 8 years. Spawns in early October. Feeds mostly on chironomids and cladocerans. Individuals translocated to reservoirs reported to grow larger and to change appearance.

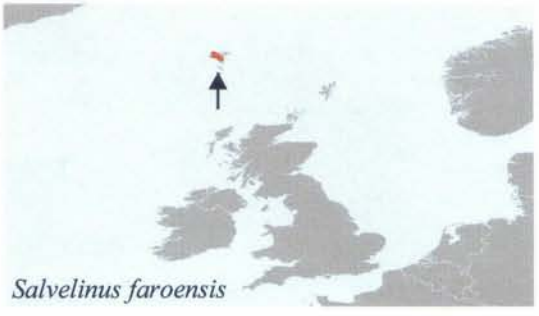
Conservation status. VU D2*.

Further reading. Joensen & Tåning, 1970: 68 (description); Malmquist et al., 2002 (biology).

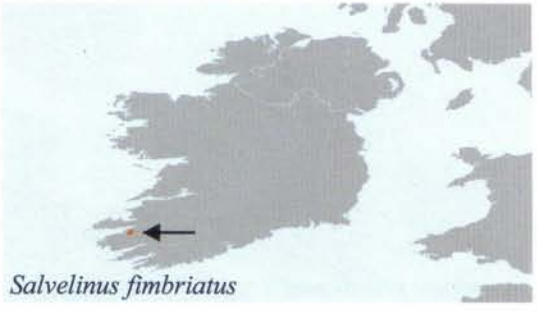
Salvelinus fimbriatus

Common name. Coomasaharn charr.

Diagnosis. Distinguished from other species of *Salvelinus* in Ireland by: ● 27-30 gill rakers, 16–20 on lower limb (vs. 11–16 in other species) /



Salvelinus faroensis



Salvelinus fimbriatus

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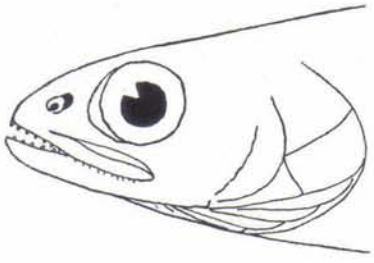
Salvelinus grayi; Loch Melvin, Ireland. A. Ferguson



Salvelinus fimbriatus; Lake Coomasaharn, Ireland; 150 mm SL. (from Regan, 1911)

Salvelinus gracillimus; Loch of Girlsta, Shetland Islands, Scotland; ~90 mm SL. G. Alexander

O body depth 20–25 % SL / O snout conical, lower jaw not included in upper one. Size up to about 200 mm SL.
Distribution. Eire: endemic to Lough Coomasaharn (Kerry), a small oligotrophic lake about 9 km from the sea.
Habitat. Lacustrine.
Biology. Spawns in November – December. Feeds exclusively on zooplankton.
Conservation status. VU D2*.
Further reading. Regan, 1908a: 232, 1911: 108 (description); Cullen et al., 2007 (morphology).

Salvelinus gracillimus

Common name. Shetland charr.
Diagnosis. Distinguished from other species of *Salvelinus* in British Isles by: ● body elongate, depth 15–18 % SL / O drab body, plain or with whitish spots / O 8–11 parr marks / O no white margins on fins. Size up to about 180 mm SL.
Distribution. Shetland Islands (Loch of Girlsta); possibly Scotland (Loch More, Sutherland).
Habitat. Lacustrine.
Biology. No data.
Conservation status. VU D2*.
Remarks. Long recorded only from Shetland Islands. This or a similar species has recently been recorded from northern Scotland. Above diagnosis based largely on latter population.
Further reading. Regan, 1911: 101 (description); Alexander & Adams, 2000: 80 (Loch More).

Salvelinus grayi

Common name. Melvin charr.
Diagnosis. Distinguished from other species of *Salvelinus* in Ireland by: O body depth 25–30 % SL / O snout conical, lower jaw not included in upper one / O length of pectoral 0.7–0.9 times in distance from its origin to pelvic origin / O body dull grey, belly yellowish to orangish / ● spots small to medium, whitish, on upper flank (and sometimes on lower flank and caudal peduncle) / ● many small whitish spots on caudal and dorsal. Size up to at least 250 mm SL.

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Salvelinus inframundus; Loch Mealt, Scotland; ~150 mm SL. G. Alexander

Distribution. Ireland: Lough Melvin.
Habitat. Lacustrine.
Biology. Lives at depths of 10–30 m, except during spawning season. Feeds on cladocera. Spawns in November, in shallow rocky area.
Conservation status. CR B1ab(iii,v)*.
Further reading. Regan, 1908a: 231, 1911: 103 (description); Ferguson, 1986 (biology); Alexander & Adams, 2000: 82 (coloration).

Salvelinus inframundus

Common name. Orkney charr.
Diagnosis. Distinguished from other species of *Salvelinus* in British Isles by: O mouth subterminal, lower jaw shorter than upper / O blunt snout / O steel-grey flank, belly white to pinkish or bright orange / O flank with numerous whitish spots, mainly in upper half of body / O pectoral and anal orange-brown to orange-red, pelvic to cherry-red, with white anterior margin (weakly in pectorals) / O pectoral about ²/₃ of head length. Size up to about 220 mm SL.
Distribution. Orkney Islands (Heldale Water, Hoy Island), Scotland (Loch Meallt, Isle of Skye).
Habitat. Loch Meallt is a small eutrophic lake, up to 3 m deep, on top of an exposed cliff.
Biology. Feeds on sticklebacks, molluscs, insect larvae.
Conservation status. DD*. Regarded as extirpated on Orkney Islands since at least 1908, but there is no recent confirmation.
Remarks. Long known only from the original description, based on material from Orkney Islands. This or a similar species has recently been recorded from Loch Meallt. Above diagnosis largely based on latter population.
Further reading. Regan, 1909: 116, 1911: 100 (description); Campbell, 1984 (feeding); Alexander & Adams, 2000: 79 (Loch Meallt).

Salvelinus killinensis

Common name. Haddy.
Diagnosis. Distinguished from other species of *Salvelinus* in Scotland by: O body olive-grey to bluish grey, with small pale spots, belly whitish / O maxilla reaching posterior margin of eye in large individuals / O length of pectoral 0.8–1.0 times in HL / O pectoral, pelvic and anal yellowish to reddish brown, narrow white anterior margin on anal and pelvic / O mouth slightly subterminal, snout obtuse. Size up to about 400 mm SL.
Distribution. Scotland: Loch Killin (Inverness-

Salvelinus inframundus

Salvelinus killinensis

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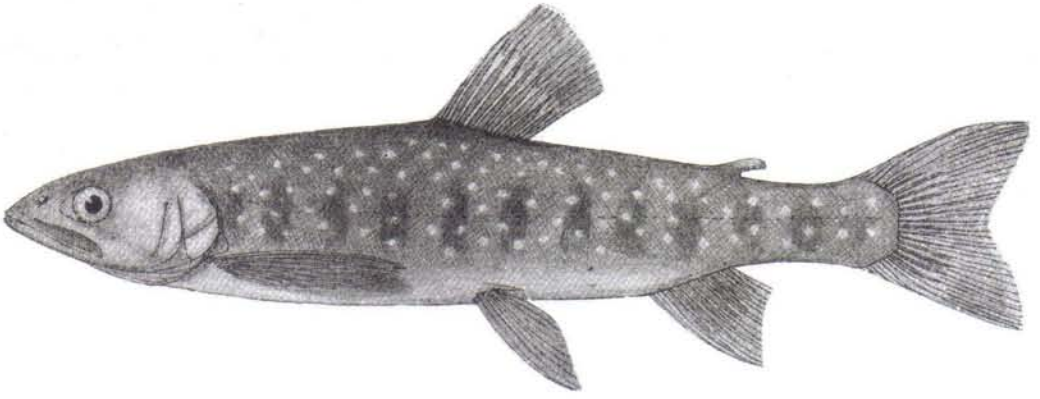
Salvelinus killinensis; Loch Doine, Scotland; ~200 mm SL. G. Alexander



Salvelinus lonsdalii; Lake Haweswater, England; 175 mm SL. (from Regan, 1911)

shire), Loch Doine (Trossachs), ? Loch Builg (Cairngorms).
Habitat. Deeper part of lakes.
Biology. In Loch Killin, moves to shallow areas to spawn. Feeds on insect larvae, bivalves and crustaceans.
Conservation status. VU D2*.
Remarks. Long formally recorded only from Loch Killin. This or similar species have recently been recorded from several other lakes of Scotland. Above diagnosis largely based on latter populations.
Further reading. Regan, 1909: 112, 1911: 96 (description); Alexander & Adams, 2000 (variability).

Salvelinus lonsdalii

Common name. Haweswater charr.
Diagnosis. Distinguished from other species of *Salvelinus* in British Isles by: ○ flank bluish brown with numerous orange spots / ○ interorbital space convex / ○ eye diameter smaller than snout length at 120–140 mm SL, 4.5–5.3 times in HL / ○ length of lower jaw more than ⅔ of HL in adult males / ○ snout conical, pointed, upper jaw not protruding / ○ maxilla extending to posterior margin of eye in adult males. Size up to about 150 mm SL.
Distribution. England: Haweswater (Cumbria).
Habitat. Deep lake.
Biology. No data.
Conservation status. CR B1ab(v) + 2ab(v)*.

Salvelinus lonsdalii

Salvelinus mallochi

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Salvelinus mallochi; Loch Shin, Scotland; ~200 mm SL. G. Alexander

Further reading. Regan, 1909: 119, 1911: 92 (description).

Salvelinus mallochi

Common name. Malloch's charr.

Diagnosis. Distinguished from other species of *Salvelinus* in British Isles by: O body pinkish grey with many large pale pinkish spots, belly white to dull orange-pink / O pectoral, pelvic and anal reddish brown, pelvic and anal with narrow anterior white margin / O body depth about 22 % SL / O eye diameter about 5.5–6.0 times in HL. Size up to about 260 mm SL.

Distribution. Scotland: Loch Scourie, Loch Shin, ? Loch a'Ghriama (Sutherland).

Habitat. Lacustrine.

Biology. No data.

Conservation status. VU D2*.

Remarks. Long known only from the original description, based on material from Loch Scourie. This or a similar species has recently been recorded from lakes of northern Scotland. Above diagnosis largely based on latter populations.

Further reading. Regan, 1909: 118, 1911: 100 (description); Alexander & Adams, 2000: 81 (variability).

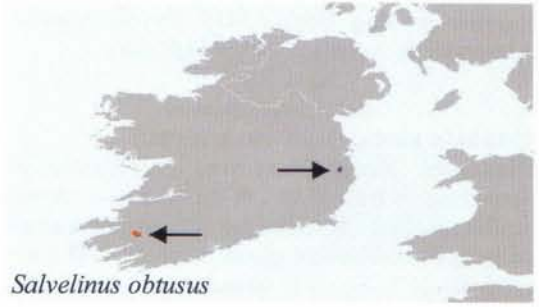
Salvelinus maxillaris

Common name. Large-mouthed charr.

Diagnosis. Distinguished from other species of *Salvelinus* in British Isles by: O lower jaw extending beyond posterior margin of eye in males larger than 200 mm SL / O body dark brown to bluish grey, with orange to red belly in adult males / ● several populations with olive to orange patch on upper part of opercle / O small orange dots on sides, mostly below lateral line / O pelvic, pectoral and anal with a conspicuous white anterior margin / O caudal with a whitish to orangish margin. Size up to 270 mm SL.

Distribution. Recorded from several lakes in northern Scotland, especially draining to North Minch (strait between Highland, Skye Island and Hebrides Islands): Loch near Ben Hope, ? Loch Merkland (Sutherland), Loch Clair, Loch Coulin, ? Loch Maree (Wester Ross), Loch Langavat, Loch

Salvelinus maxillaris



Salvelinus obtusus

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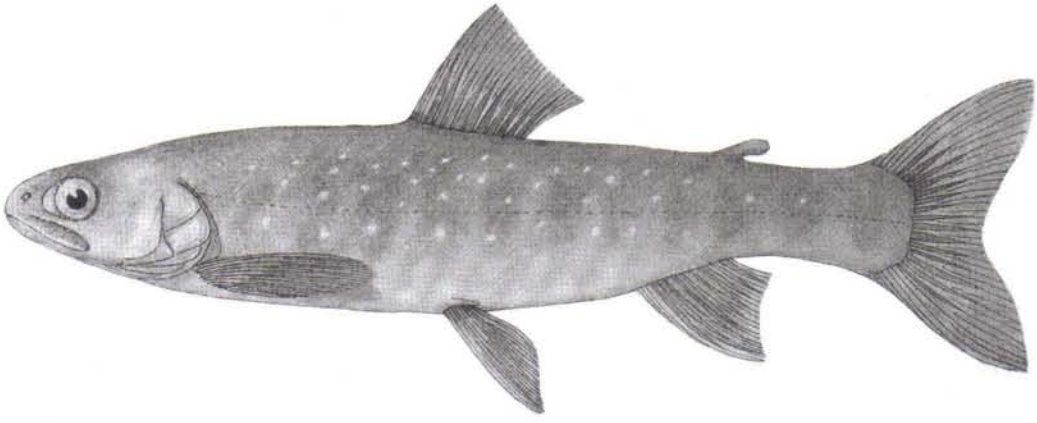
Salvelinus cf. *maxillaris*; Loch Merkland, Scotland; ~180 mm SL. G. Alexander



Salvelinus obtusus; Killarney, Ireland; 200 mm SL. (from Regan, 1911)

na Craobhaig (Isle of Lewis).
Habitat. Lacustrine.
Biology. No data.
Conservation status. VU D2*. Long known only from the original description, based on material from a lake near Ben Hope. This or a similar species has recently been recorded from several lakes of northern Scotland. Above diagnosis largely based on latter populations.
Further reading. Regan, 1911: 99 (description); Alexander & Adams, 2000 (variability).

Salvelinus obtusus

Common name. Blunt-snouted charr.
Diagnosis. Distinguished from other species of *Salvelinus* in Ireland by: ● snout obtuse, dorsal profile rounded / ● lower jaw shorter and included in upper jaw when mouth is closed / ○ body depth 20–25 % SL. Size up to at least 180 mm SL.
Distribution. Eire: Loughs Leane and Muckross (Kerry). Believed to have existed or that similar charrs existed in Loughs Tay, Dan (Wicklow), Acoose (Kerry), and Nalughraman (Donegal).
Habitat. Lacustrine.
Biology. No data.
Conservation status. CR B1ab(iii)*. Extirpated in Loughs Acoose, Tay and Dan. Not recorded in Muckross since 1904. Eutrophication is still a problem in Lough Leane.
Further reading. Regan, 1908a: 233, 1911: 109 (description); Igoe et al., 2003 (distribution).

Salvelinus perisii

Common name. Torgoch.
Diagnosis. Distinguished from other species of *Salvelinus* in British Isles by: ○ flank greenish brown with orange spots, belly orange (also in some females) / ○ pectoral, pelvic and anal or-

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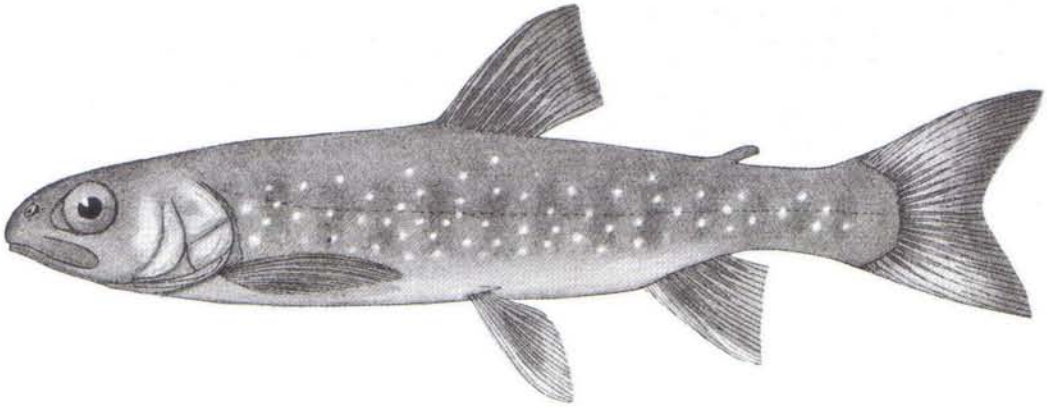
Salvelinus perisii; Lake Cwellyn, Wales. I. McCarthy



Salvelinus sp. Rannoch benthivorous (?); Loch Rannoch, Scotland; 210 mm SL. (from Regan, 1911)

ange, with white anterior margin / ● interorbital space flat, with eyes almost flush with dorsal profile in lateral view / ○ eye diameter smaller than snout length at 120–140 mm SL, 4.3–5.0 times in HL / ● snout conical, pointed, lower jaw projecting / ○ maxilla reaching posterior margin of eye in adult males. Size up to about 250 mm SL.

Distribution. Wales: Lakes Llyn Peris, Padarn, Cwellyn and Bodlyn (Gwynedd).

Habitat. Deep lakes.

Biology. Forms shoals at surface in summer, probably for feeding on insects or plankton. Spawns in November – December. In Llanberis lakes, used to move in November from lower lake (Llyn Padarn) to lower part of upper lake (Llyn Peris), where it spawned in shallow areas. Construction of Dinorwic hydroelectric scheme disrupted this migration; now mainly living and spawning in Llyn Padarn.

Conservation status. VU D2*.

Further reading. Regan, 1909: 114, 1911: 93 (description); Child, 1977 (genetics).

Salvelinus struanensis

Common name. Rannoch planktivorous charr.

Diagnosis. Distinguished from other species of *Salvelinus* in central Scotland by: ● overall claret colour in breeding season, often with dark fins and orange-pink spots / ○ no parr marks / ● mouth oval when open / ○ body fusiform. Size up to about 360 mm SL.

Distribution. Scotland: Loch Rannoch and Loch Ericht.

Habitat. Pelagic zone of fjord-like lakes, usually less than 20 m below surface.

Biology. Reaches up to 8 years. Adult males have dark red flank and belly, white pelvic-fin edges.

Salvelinus perisii

Salvelinus struanensis

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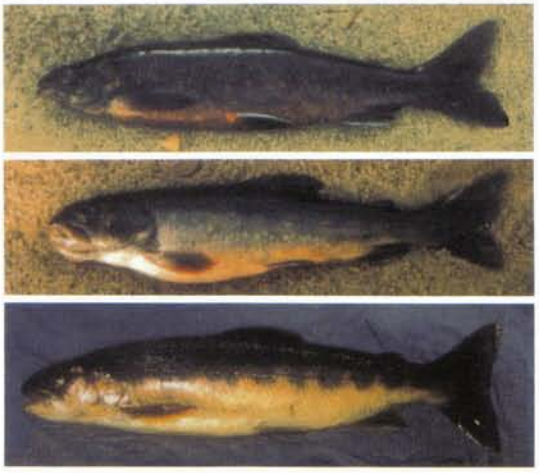


Three sympatric *Salvelinus* species in Loch Rannoch, Scotland. From top to bottom: *S. struanensis*, *S.* sp. piscivorous, and *S.* sp. benthivorous. G. Alexander

Spawns in late September – October on gravels along shelving shores of lakes. Feeds on zooplankton, especially Cladocera (*Daphnia*).
Conservation status. VU D2*.
Further reading. Walker et al., 1988 (biology, morphology); Hartley et al., 1992 (genetics); Kottelat, 1997 (systematics); Adams et al., 1998 (morphology); Fraser et al., 1998 (morphology).

Salvelinus sp. Rannoch benthivorous

Common name. Ranoch benthivorous charr.
Diagnosis. Distinguished from other species of *Salvelinus* in central Scotland by: O overall pale grey or brown body, with lemon fins and no obvious spots / O parr marks present / O maxilla reaching posterior margin of eye / O mouth round when open. Size up to about 210 mm SL.
Distribution. Scotland: Loch Rannoch.
Habitat. Benthic zones of fjord-like lake.
Biology. Reaches up to 12 years. No known sexual colour dimorphism at maturity. Spawns in November – December in shallow water in slow current of estuary of River Gaur. Feeds on a variety of benthic invertebrates (especially Trichoptera and chironomid larvae and bivalves).

Salvelinus willoughbii; Lake Windermere, England; ~220 mm SL. CEH/FBA

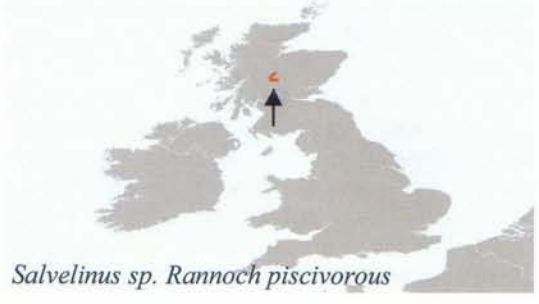
Conservation status. VU D2*.
Further reading. Walker et al., 1988 (biology, morphology); Hartley et al., 1992 (genetics); Kottelat, 1997 (systematics); Adams et al., 1998 (morphology, biology); Fraser et al., 1998 (morphology).

Salvelinus sp. Rannoch piscivorous

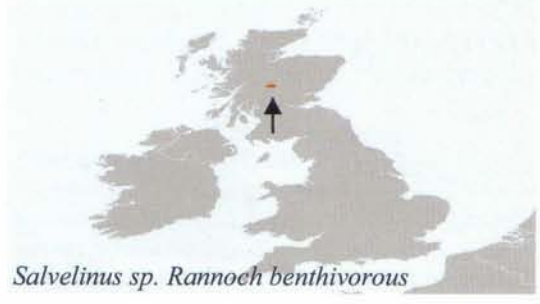
Common name. Rannoch piscivorous charr.
Diagnosis. Distinguished from other species of *Salvelinus* in central Scotland by: O overall pale grey or brown body, with lemon fins and no obvious spots / O parr marks present / O maxilla reaching beyond posterior margin of eye / O mouth round when open. Size up to about 350 mm SL.
Distribution. Scotland: Loch Rannoch and Loch Ericht.
Habitat. Benthic zones of fjord-like lakes.
Biology. Reaches up to 18 years. No known sexual colour dimorphism at maturity. Spawns in October – November in shallow water. Feeds mainly on fish, marginally on benthic invertebrates.
Conservation status. VU D2*.
Further reading. Kottelat, 1997 (systematics); Adams et al., 1998 (morphology, biology).

Salvelinus willoughbii

Common name. Autumn Windermere charr.
Diagnosis. Distinguished from other species of *Salvelinus* in British Isles by: O flank bluish brown with numerous medium orange spots, belly orange / O pectoral, pelvic and anal reddish brown



Salvelinus sp. Rannoch piscivorous



Salvelinus sp. Rannoch benthivorous

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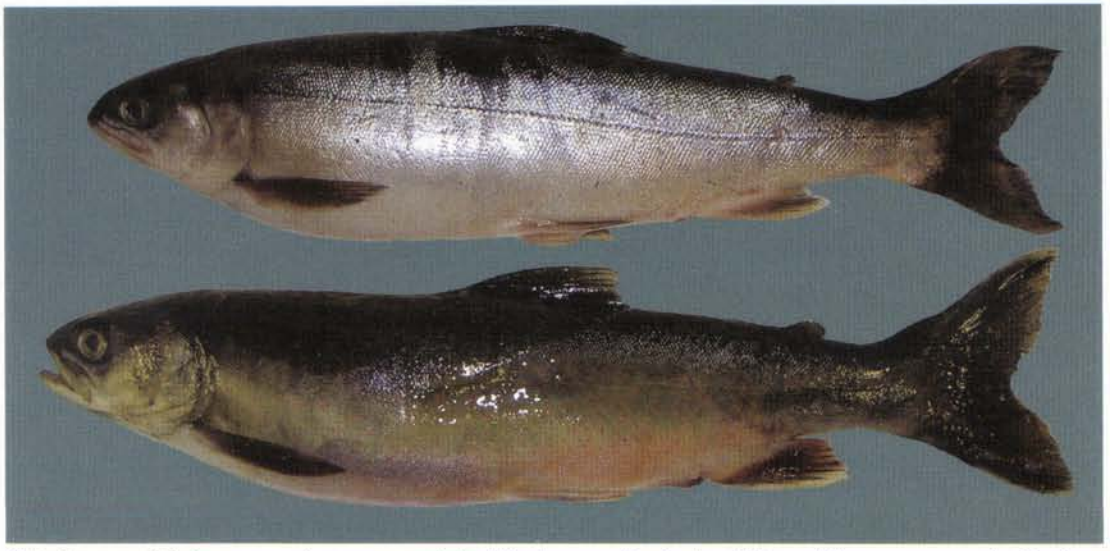

Salvelinus sp. Windermere spring spawner; Lake Windermere, England; ~230 mm SL. L. Corrigan

to bright red, with white anterior margin / ♂ interorbital space convex / ♂ eye diameter about equal to snout length at 120–140 mm SL, 4.3–5.9 times in HL / ♂ length of lower jaw at most ⅔ of HL / ♂ snout conical, upper jaw not protruding / ♂ maxilla reaching posterior margin of eye in adult males / ♂ 11–16 gill rakers on lower limb. Size up to about 300 mm SL.

Distribution. England: Lakes Windermere and ? Ennerdale Water (Cumbria).

Habitat. Deep lakes.

Biology. Spawns in early November, in shallow water (1–3 m deep) and in main tributaries, on stone bottom. Eggs hatch in 64–80 days.

Conservation status. EN B1ab(iii) + 2ab(iii)*.

Remarks. Spring and autumn spawning charrs occur sympatrically in Windermere; they do not interbreed in the wild (but can be crossed under laboratory conditions) and are reportedly not distinguishable morphologically except by gill raker counts (which broadly overlap) and more brilliant coloration for the spring spawner. Another morphological study concluded that they differ, but did not explicitly state how they differ. There are indications that they are genetically isolated, for which reason they are here treated as distinct species. Autumn and spring spawners occur in other Cumbrian lakes but they co-occur only in Windermere. No information is available on spawning period of charrs in other Cumbrian lakes (Goat's Water, Wast Water, Lowes Water). The Ennerdale population is said to be phenotypically distinct, but the differences have never been described; its status cannot therefore be evaluated.

Differences between *S. willoughbii* and *S. maxillaris* are slight and they are possibly conspecific. In the past, numerous populations in intermediate areas have been referred to *S. willoughbii*, but more data are needed to decide their identity.

Further reading. Regan, 1909: 114, 1911: 85 (description); Frost, 1966 (biology); Child, 1984 (genetics); Partington & Mills, 1988 (morphology, genetics); Kottelat, 1997: 156 (nomenclature).

***Salvelinus* sp. Windermere spring spawner**

Common name. Spring Windermere charr.

Diagnosis. Distinguished from sympatric *S. willoughbii* in Cumbrian lakes by: ♂ 23–29 gill

Salvelinus willoughbii

Salvelinus sp. Windermere spring spawner

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Salvelinus cf. *youngeri*; Loch Earn, Scotland; ~180 mm SL.

rakers, usually 25–27 (vs. 20–27, usually 21–25) / ○ gill raker length 1.3–2.0 % SL (vs. 0.8–1.4) [the study reporting a difference in gill raker length does not explain how gill raker length was measured; we assume that the longest gill raker was measured, at the angle between the upper and lower limbs of the gill arch]. Size up to about 350 mm SL.

Distribution. England: Lakes Windermere, Coniston Water, ? Buttermere and ? Crummock Water (Cumbria).

Habitat. Deep lakes.

Biology. Spawns in January – March in deep water (10–20 m) on stone bottom. Eggs hatch in 70–80 days.

Conservation status. EN B1ab(iii) + 2ab(iii)*.

Further reading. Regan, 1909: 114, 1911: 85 (description); Frost, 1966 (biology).

Salvelinus youngeri

Common name. Golden charr.

Diagnosis. Distinguished from other species of *Salvelinus* in British Isles by: ○ body plain purplish-brown (silvery to goldish outside spawning season), belly creamy-pink to light orange in large individuals / ○ eye large, about 3.7–4.0 times in HL / ○ snout blunt / ○ pectoral equal to or longer than head, sometimes almost reaching pelvic origin in large males / ○ pectoral, pelvic and anal reddish, pelvic and anal with white anterior margin, very narrow in pectoral / ○ maxilla reaching posterior margin of eye or beyond. Size up to about 250 mm SL.

Distribution. Scotland: Loch Eck, ? Loch Awe (Argyll), ? Loch Lee (Angus), ? Loch Earn (Perthshire), ? Loch Doon (Ayrshire); Loch Doon population has been introduced in Megget and Talla reservoirs.

Habitat. Lacustrine.

Biology. In Loch Doon: Lives up to 9 years.

Loch Earn, Scotland; habitat of *Salvelinus* cf. *youngeri*.

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Salvelinus sp. Loch Awe spring spawner; Loch Awe, Scotland; ~180 mm SL. G. Alexander

Spawns in October, over gravel and stones in shallow water, along stone shore line. Feeds on zooplankton in summer, on benthic invertebrates rest of year.

Conservation status. VU D2*. Threatened by acidification (acid rains) and afforestation with coniferous.

Remarks. Long recorded only from the original description, based on material from Loch Eck. Above diagnosis based on Loch Eck population. This or similar species have recently been recorded from several lakes of western and central Scotland; they differ in having a somewhat smaller eye (4.0–4.5 times in HL), darker body, and small pale spots, often indistinct. Loch Doon population is reporded to have a "substantially lower" number of branchiostegal rays [actual numbers not stated], which, if confirmed, suggests it could be a distinct species.

Further reading. Friend, 1956: 220 (diagnosis); Maitland et al., 1991 (ecology, Loch Doon); Alexander & Adams, 2000: 82 (description).

***Salvelinus* sp. Loch Awe spring spawner**

Common name. Spring Awe charr.

Diagnosis. Distinguished from other species of *Salvelinus* in Scotland by: ○ body dark bluish brown, belly pale brownish orange / ○ indistinct orange spots on lower flank / ○ fins dark brown / ○ white anterior margin on anal and pelvic / ○ maxilla reaching slightly beyond posterior margin of eye / ○ body depth 19–22 % SL. Size up to about 250 mm SL.

Distribution. Scotland: Loch Awe (Argyll).

Habitat. Lacustrine.

Biology. Spawns in early March.

Conservation status. DD**.

Further reading. Alexander & Adams, 2000: 79 (description).

***Salvelinus* sp. Loch Maree large eye**

Common name. Big-eyed Maree charr.

Diagnosis. Distinguished from other species of *Salvelinus* in British Isles by: ● eye very large, 2.9–3.5 times in HL / ○ snout blunt / ○ flank pinkish brown, belly white to yellowish white / ○ about 8 parr marks / ○ no pale spots on flank / ○ yellow to bright red pectoral and pelvic. Size up to about 170 mm SL.

Distribution. Scotland: Loch Maree (Wester Ross).

Habitat. Lacustrine.

Biology. No data.

Salvelinus youngeri

Salvelinus sp. Loch Awe spring spawner

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Salvelinus sp. Loch Maree large eye; Loch Maree, Scotland; ~100 mm SL. G. Alexander

Salvelinus sp. Loch Maree slender; Loch Maree, Scotland; ~100 mm SL. G. Alexander

Conservation status. DD**.
Further reading. Alexander & Adams, 2000: 82 (description).

***Salvelinus* sp. Loch Maree slender**
Common name. Slender Maree charr.
Diagnosis. Distinguished from other species of *Salvelinus* in Scotland by: O eye large, about 3.5–4.3 times in HL / O flank silvery to bluish or pinkish grey, with 6–10 parr marks and moderate number of large pale spots / O belly light grey to white / O body depth 18–23 % SL / O pectoral, pelvic and anal dark brown to reddish brown, pelvic and anal with white anterior margin / O maxilla reaching just beyond posterior margin of eye. Size up to about 180 mm SL.
Distribution. Scotland: Loch Maree, ? Lochan Uaine, ? Loch Coulin (Wester Ross).
Habitat. Lacustrine.
Biology. No data.
Conservation status. DD**.
Further reading. Alexander & Adams, 2000: 82 (description).

Iceland

Charrs from Iceland have usually been considered as conspecific with those from Europe, especially Scandinavia, but there has not been a real comparison. We tentatively admit that true *S. alpinus* exists in Iceland (see above, under Scandinavia). Lake Thingvalla is noteworthy for the sympatric occurrence of what were considered to be four morphs of the same species. The published data, however, shows that three (if so, one with a planktivorous and a piscivorous growth phases) or four species are involved. Available data do not facilitate a decision on whether or not they are restricted to Lake Thingvalla and whether one of them could be conspecific with the '*S. alpinus*' outside the lake. There are no published data allowing a comparison of non-lacustrine Icelandic *Salvelinus* with European species.

Other cases of lakes with polymorphic species or sympatric species are known in Iceland, but there are few published data and they do not allow a decision with regard to their identity. There

Salvelinus sp. Loch Maree slender

Salvelinus sp. Loch Maree large eye

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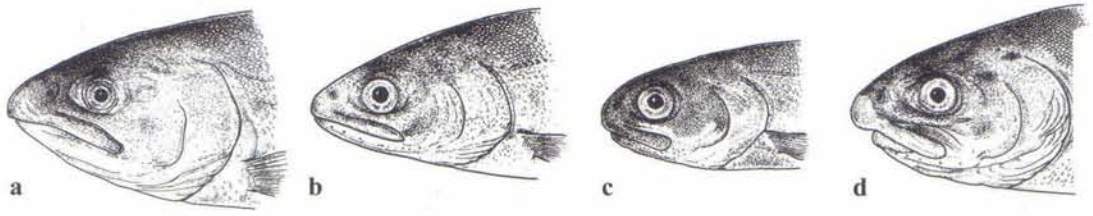
Salvelinus sp.; Lake Reydarvatn, Iceland; 335 mm SL. B. Delling

Salvelinus sp.; Lake Reydarvatn, Iceland; 257 mm SL. B. Delling

Salvelinus sp.; a dwarf form from Hlaupstjörn, Iceland; 127 mm SL. G. Fridriksson



Heads of *Salvelinus* species in Lake Thingvalla, Iceland. **a,** *S. murta*, piscivorous morph; **b,** *S. murta*, planktivorous morph; **c,** *S. thingvallensis*; **d,** *S.* sp. large benthivorous. (from Sandlund et al., 1992, reproduced by permission of *Oikos*)

are also records of very small water bodies inhabited by dwarf species.

Salvelinus murta

Common name. Murta.

Diagnosis. Distinguished from other species of *Salvelinus* in Iceland by: ○ flank silvery bluish, without parr marks, with paler spots (breeding males become brownish with yellowish spots) / ○ pectoral, pelvic and anal without conspicuous white anterior margin / ○ snout conical, longer than eye diameter / ○ mouth subterminal, upper jaw projecting only slightly. Size up to 200 mm SL in planktivorous individuals, 480 mm SL in piscivorous ones.

Distribution. Iceland: Lake Thingvalla.

Habitat. Open waters.

Biology. Pelagic. Lives up to 18 years. Spawns for

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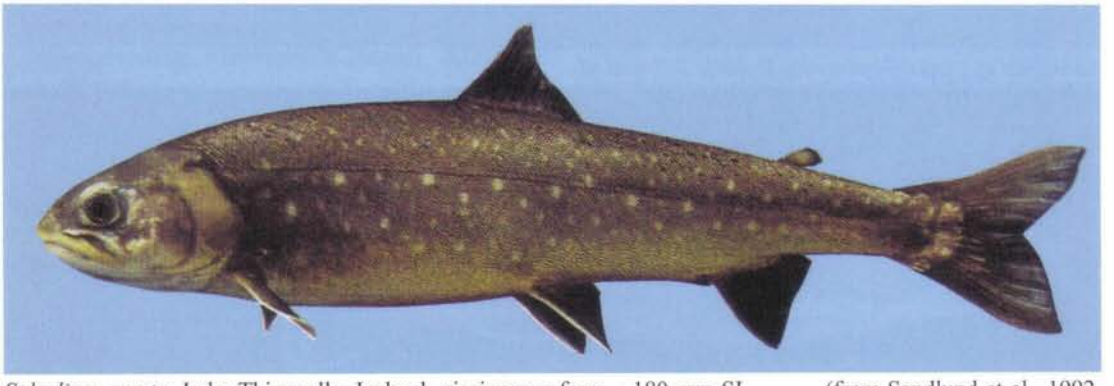
Lake Thingvalla, Iceland.



Salvelinus murta; Lake Thingvalla, Iceland; piscivorous form, ~180 mm SL. (from Sandlund et al., 1992, reproduced by permission of *Oikos*)

Salvelinus murta; Lake Thingvalla, Iceland; piscivorous form. B. Delling

the first time at 3–6 years. Spawns in October. Feeds on zooplankton (*Daphnia*, *Cyclops*) and insects. A few individuals are piscivorous, have a slightly different morphology, tend to live closer to shores, grow large and develop a colour pattern somewhat similar to *S. thingvallensis*; they feed mainly on *Gasterosteus islandicus*, supplemented by small planktivorous conspecifics. Earlier data indicated that they are a larger growth phase but recent ones suggest that they might be a distinct species.

Conservation status. LC*.

Further reading. Sandlund et al., 1992 (biology; as piscivorous and planktivorous forms); Kottelat, 1997: 149 (systematics).

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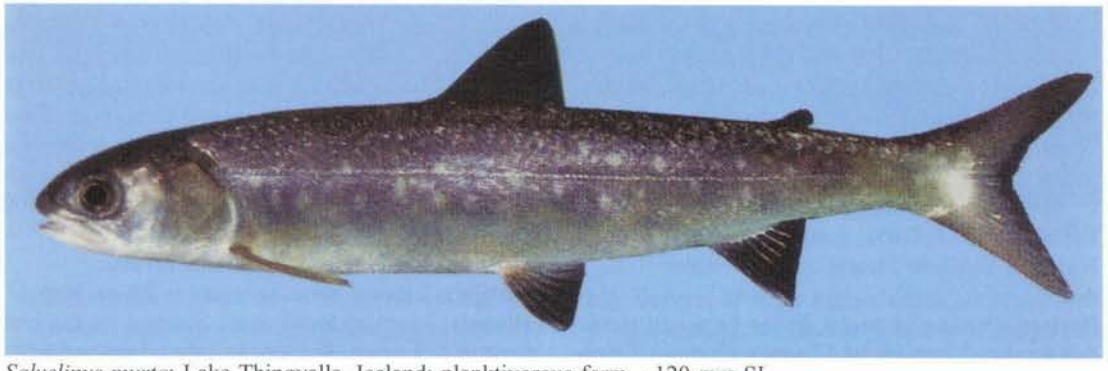
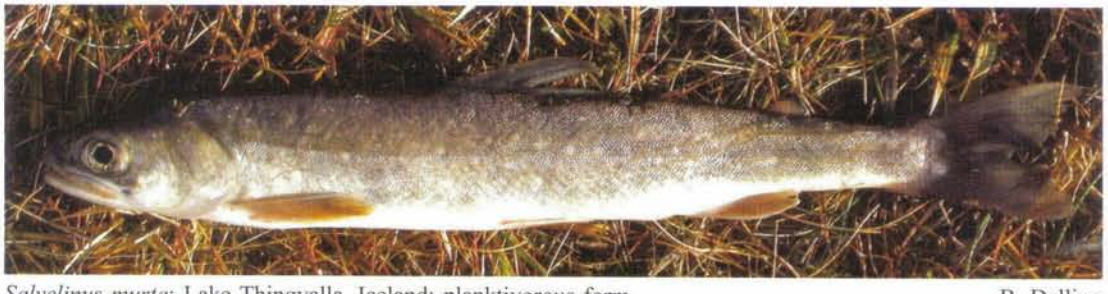
G. Fridriksson



Salvelinus murta; Lake Thingvalla, Iceland; planktivorous form, ~120 mm SL.
(from Sandlund et al., 1992, reproduced by permission of *Oikos*)



Salvelinus murta; Lake Thingvalla, Iceland; planktivorous form. B. Delling

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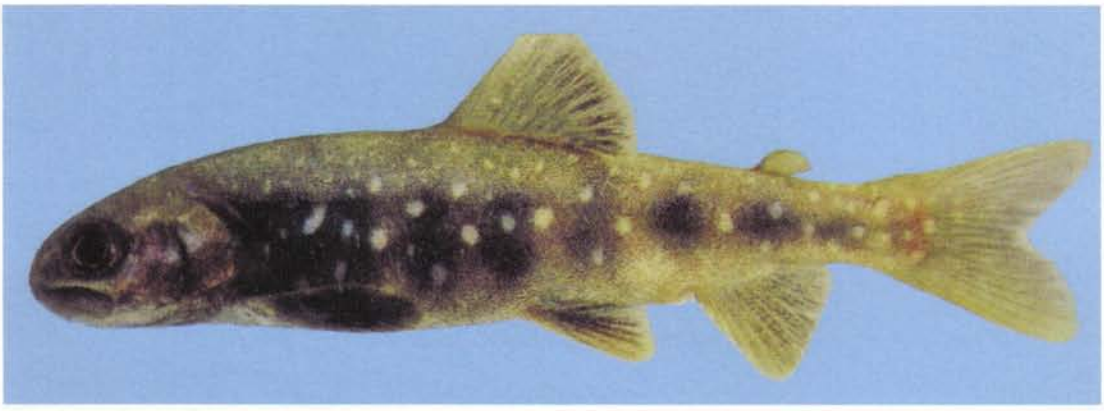

Salvelinus thingvallensis; Lake Thingvalla, Iceland; ~110 mm SL. (from Sandlund et al., 1992, reproduced by permission of *Oikos*)

Salvelinus thingvallensis

Common name. Gjámurta [fissure murta].

Diagnosis. Distinguished from other species of *Salvelinus* in Iceland by: ● parr marks present in adults / ● flank dark brown with irregular golden or yellow spots, belly beige to yellowish, usually blackish markings on throat (not much difference between breeding and non-breeding coloration) / ● pectoral black, other fins beige, caudal and dorsal with pale spots / ● snout blunt, rounded, about equal to eye diameter / ○ mouth subinferior, upper jaw projecting. Size up to 240 mm SL.

Distribution. Iceland: Lake Thingvalla.

Habitat. Shallow littoral zone, in water 0–10 m deep.

Biology. Active at night, hides between stones during day. Lives up to 17 years. Spawns for the first time at 2–4 years. Usually spawns in October – November, but in areas with cold water springs some individuals may spawn in July – September. Feeds mainly on snails, and to a lesser extent on benthic insects.

Conservation status. LC*.

Further reading. Sandlund et al., 1992 (biology; as small benthivorous form); Kottelat, 1997: 149 (systematics).

Salvelinus sp. Thingvalla large benthivorous

Common name. Large benthivorous Thingvalla charr.

Diagnosis. Distinguished from other species of *Salvelinus* in Iceland by: ○ flank olive brown, without parr marks, with orange spots, rarer in upper flank / ● pectoral, pelvic and anal with conspicuous white anterior margins, caudal with white upper and lower margins, dorsal with white anterior margin / ○ belly yellow to orange / ● snout rounded, longer than eye diameter / ○ mouth subinferior, upper jaw projecting. Size up to 400 mm SL.

Distribution. Iceland: Lake Thingvalla.

Habitat. Littoral zone, in water 0–20 m deep.

Biology. Lives up to 14 years. Spawns for the first time at 4–5 years. Spawns in July – September, in areas with cold-water springs, at 3–4°C. Feeds mainly on snails and insects.

Conservation status. LC**.

Further reading. Sandlund et al., 1992 (biology); Kottelat, 1997: 149 (systematics).

Central Europe

In Alpine lakes, various *Salvelinus* forms have traditionally been recognized, with up to three being reported from a single lake. For example,charrs

Salvelinus sp. Thingvalla large benthivorous

Salvelinus evasus

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Salvelinus sp. Thingvalla large benthivorous; Lake Thingvalla, Iceland; ~340 mm SL.
(from Sandlund et al., 1992, reproduced by permission of *Oikos*)

Salvelinus sp. Thingvalla large benthivorous; Lake Thingvalla, Iceland. B. Delling

called 'wildfangsaibling', 'normalsaibling' and 'schwarzreuter' were originally recognized in Lake Königssee (Germany). They are apparently different growth phases of the same species. In some lakes, schwarzreuter are called tiefseesaibling while in other lakes the word tiefseesaibling is applied to what in fact is a distinct species. In cases of sympatry, this often involves a 'normal' and a deepwater stock. Such cases have been reported at least from Lakes Constance, Neuchâtel, Bourget, Walchensee, Tegernsee, Achensee, Plansee, Attersee and Traunsee, but some of these records are dubious. In Lake Constance, the two species differ in habitat, life history, external morphology and osteology. Only few Central European deepwater stocks have been described in some detail and these have been found to be distinct species. Several of the deepwater populations are already extirpated or seriously threatened, but some new ones have also been discovered in recent years. Generally, the diversity of Alpine charrs seems to be largely underestimated and several lakes might be inhabited by endemic species.

The status of populations of high-altitude lakes is more difficult to evaluate, especially as it is likely that most (or all) of them are the result of stocking. Several of these high-altitude lakes are located at the edges of glaciers and are of very recent age. Longitudinal movements of several Alpine glaciers are quite well documented in historical times. Alpine glaciers had a maximum extension in the 17th century and have significantly regressed in the last 150 years (the Rhône glacier regressed 2200 m between 1818 and 1980). It is necessary to determine the origin of the transplanted or colonising stocks before discussing their taxonomic status.

Salvelinus evasus

Common name. Ammersee saibling.

Diagnosis. Distinguished from other species of *Salvelinus* in central Europe by: ○ pelvic fin not reaching anus / ○ mouth subinferior, lower jaw included in upper jaw / ○ snout blunt / ○ 19–27 gill rakers / ○ flank yellowish to silvery, with faint pale spots, lower part yellowish to pale orange in mature males / ○ eye diameter 0.8–1.4 times in interorbital distance, 19–26 % HL / ● fins hyaline to whitish, with white margins in mature males / ○ head depth at eye 9–11 % SL / ○ body depth at anal origin 10–15 % SL. Size up to about 300 mm SL, reportedly grows larger.

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Salvelinus evasus; Lake Ammersee, Germany; nuptial female (upper) 256 mm SL; nuptial male (lower) 253 mm SL.

Salvelinus neocomensis; Lake Neuchâtel, Switzerland; 151 mm SL.

Distribution. Germany: Lake Ammersee.
Habitat. Deep water (below 80 m).
Biology. Almost no data. Spawns in all seasons with a peak in September and October.
Conservation status. VU D2*.
Remarks. The deep water charr reported from Lake Attersee is most likely not conspecific with *S. evasus*.
Further reading. Freyhof & Kottelat, 2005: 259 (description).

Salvelinus neocomensis

Common names. Jaunet, biblet.
Diagnosis. Distinguished from other species of *Salvelinus* in central Europe by: ● pelvic fin reaching to anus in males / ○ flank yellowish, fins without white margins / ○ mouth subinferior, lower jaw included in upper jaw / ○ snout blunt / ○ eye diameter 1.0–1.1 times in interorbital distance, 24–25 % HL / ○ body depth at anal origin 13–16 % SL / ● 21–23 gill rakers. Size up to about 150 mm SL.
Distribution. Lake Neuchâtel (Switzerland).
Habitat. Deep water (below 80 m).

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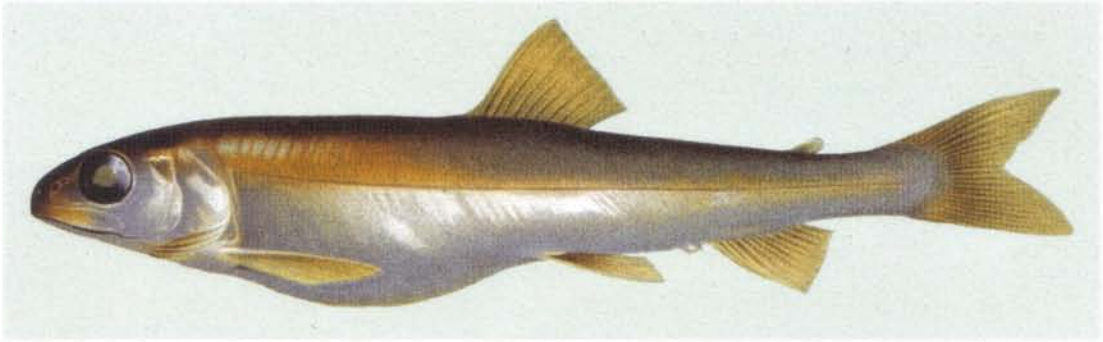

Salvelinus profundus; Lake Constance, Germany; ~85 mm SL. (from Vogt & Hofer, 1908-09)

Biology. Spawns on muddy (?) sediments in May – August. Feeds mainly on insect larvae, snails, crustaceans and fish eggs.
Conservation status. Extinct*.
Remarks. *S. neocomensis* was known definitely only from Lake Neuchâtel where it is now reported to be extinct. In Lake Bourget (France), fishermen report the earlier presence of a small yellowish deepwater *Salvelinus* whose identity cannot be established.
Further reading. Quartier, 1951 (biology); Freyhof & Kottelat, 2005: 256 (description).

Salvelinus profundus

Common name. Tiefseesaibling.
Diagnosis. Distinguished from other species of *Salvelinus* in central Europe by: ○ pelvic fin not reaching anus / ○ mouth subinferior, lower jaw included in upper jaw / ○ snout blunt / ○ 19–27 gill rakers / ● flank yellowish to silvery, sometimes with faint pale spots, belly sometimes reddish / ○ fins brownish to reddish brown, without white margins / ○ eye diameter 1.3–1.5 times in interorbital distance, 19–21 % HL / ○ body depth at anal origin 15–16 % SL. Size up to about 240 mm SL.
Distribution. Lake Constance (Switzerland, Germany, Austria).
Habitat. Deep water (below 80 m). Lives and feeds on bottom.
Biology. When brought to surface in nets, usually appears with a greatly bloated belly because of expansion of gas bladder resulting from reduction of water pressure. Possibly spawns on an extended period between July – February (or maybe even at all seasons), at depths around 60–80 m, on pebble bottom. Feeds mainly on cocoons of Turbellaria and copepods.
Conservation status. Extinct.
Remarks. *S. profundus* was known definitely only from Lake Constance where it is now extinct. Although a local population is now sometimes recorded as tiefseesaibling, this is not the original one but a phase of *S. umbla*.

Salvelinus profundus; Lake Constance, Germany; 175 mm SL; mouth in ventral view showing lower jaw included in upper jaw.

Further reading. Dörfel, 1974 (diagnosis, biology); Freyhof & Kottelat, 2005: 255 (description, status).

Salvelinus umbla

Common name. Alpine charr.
Diagnosis. Distinguished from other species of *Salvelinus* in central Europe by: ● terminal to subterminal mouth, lower jaw not included in upper jaw / ● snout conical / ● 25–31 gill rakers / ● flank greenish brown with reddish spots, belly yellowish to reddish orange / ● fins red to orange with white margins. Size up to about 750 mm SL, but usually not over 400 mm SL.
Distribution. Alpine and subalpine lakes in Italy (Trentino, Alto Adige), France (Lake Bourget), Switzerland, Germany and Austria. Introduced in numerous high altitude lakes.
Habitat. Deep lakes in glacial valleys, high altitude lakes.
Biology. Spawns for the first time at 2–3 years. Spawns in November – December, on pebble to stone bottom on steep slopes, at 30–120 m depth. Feeds on crustaceans, insects and benthic fauna; a few individuals develop as large piscivores, with

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Salvelinus umbla; Lake Constance, Germany; foraging phase, ~300 mm SL.

Salvelinus umbla; Lake Chiemsee, Germany; nuptial male, ~350 mm SL. A. Hartl

a distinct morphology. Numerous dwarf, stunted populations exist in Alpine lakes (up to 2680 m); all seem to result from introductions.

Conservation status. LC*, but several populations have declined, are maintained only by stocking programs or by transplantation from other lakes.

Remarks. The different populations grouped here under *S. umbla* exhibit a great diversity of shape and coloration; detailed comparative studies are needed to establish their identities.

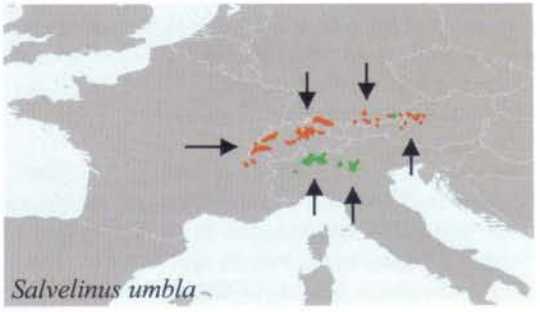
Further reading. Ruhlé, 1977 (biology); Balon & Penczak, 1980 (Alpine populations); Champigneulle & Gerdeaux, 1995 (biology).

Salvelinus fontinalis

Common name. Brook charr.

Diagnosis. Distinguished from other species of *Salvelinus* in Europe by: ○ caudal truncate or only slightly emarginate / ● back, dorsal and caudal with pale spots or vermiculated / ○ pectoral, pelvic and anal with white margin followed by a black submarginal line / ○ flank with pink or red spots, some bluish / ○ juvenile with 8–10 parr marks. Size up to about 500 mm SL.

Distribution. Native to North America from Hudson Bay basin and northeastern Canada south to upper Mississippi, east to coast of New Jersey and northern Georgia. Widely introduced in North and South America, Europe, Asia, and Southern Africa. Stocked throughout Europe, especially in high altitude streams and lakes but rarely confirmed as established. Established populations documented from high altitude lakes and streams in Corsica, Italy, Czechia, southern Germany (list unlikely to



Salvelinus umbla; aquaculture, Germany; juvenile, ~130 mm SL. A. Hartl

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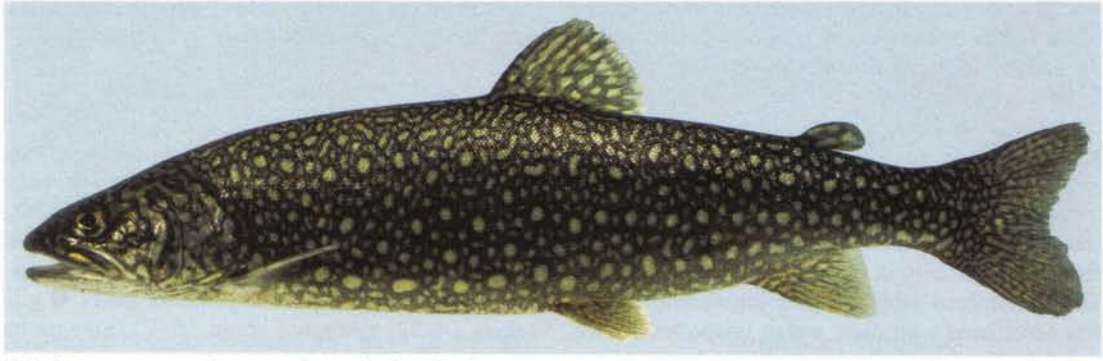
Salvelinus fontinalis; aquaculture, Germany; ~300 mm SL. A. Hartl



Salvelinus namaycush; aquaculture, Switzerland; ~300 mm SL. M. Roggo

be exhaustive).

Habitat. Cold and moderate to fast-flowing mountain streams. In North America, northern populations also in lakes and rivers. Spawns in gravel in fast-flowing streams or in lakes. Occasionally established in nutrient poor lakes, high mountain or acidic streams.

Biology. Lives up to 15 years. Spawns for the first time at 1–2 years in central and southern Europe, 3–4 years in northern Europe. Spawns in October – November, earlier in the north, usually at 3–10°C. Females construct redds. Eggs hatch in spring. In Europe, only non-anadromous populations. In North America, anadromous as well. Feeds on aquatic invertebrates and small fish. Territorial, at equal size, dominated by *Salmo trutta* whose presence is a factor limiting its distribution. Artificial hybrids with *Salmo trutta* (tiger trout) are occasionally stocked.

Conservation status. Alien.

Further reading. Scott & Crossman, 1973: 217 (biology); Jenkins & Burkhead, 1993: 575 (biology).

Salvelinus namaycush

Common name. American lake trout.

Diagnosis. Distinguished from other species of *Salvelinus* in Europe by: ○ caudal deeply forked / ● head, body, dorsal and caudal dark brown, covered by small pale spots. Size up to about 1000 mm SL, usually 350–450 mm SL.

Distribution. Native to North America from Great Lakes to Alaska. Introduced to Europe in 1881. Reported to be established especially in high altitude lakes. Established breeding populations in Pyrénées (France), northern Italy and Lakes Storjön, Kallsjön (Jämtland Province, Sweden) and Inarinjärvi (Finnish Lapland). Locally introduced in lakes of Massif Central (France) and Alps (France, Switzerland) where it apparently survives only by stocking.

Habitat. Lacustrine, rarely riverine. Prefers water layers around 10°C.

Biology. Lives up to 25 years. Spawns for the first time at 6–7 years. In native range, spawns in October – December, on stone bottom of lakes, rarely in rivers, at 1–36 m depth, at 9–14°C. Eggs hatch in 4–5 months, in March – April. Feeds on plankton, insects and fishes.

Conservation status. Alien.

Further reading. Scott & Crossman, 1973: 237 (biology).

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Family Thymallidae

Graylings

A small family of circumpolar distribution with one genus and about 10–20 species, most diverse in northern East Asia, especially in Amur drainage (4 species). Distinguished from other freshwater fishes by the presence of an adipose dorsal fin and by its large dorsal. All graylings inhabit fast-flowing waters of cold and well oxygenated rivers and streams. Lacustrine populations are known from Nordic lakes throughout the range. Most lacustrine populations migrate to lake tributaries to spawn. Graylings are of minor commercial value but play an important role in recreational fisheries especially in western and central Europe. The recreational aspect of grayling fishing is usually associated with clear water, unspoiled nature and the "fight" with the hooked fish. In most cases, recreational fisheries are not sustainable, especially in densely populated areas and in disturbed rivers. To maintain high enough population densities (or to maintain them at all), large numbers of fingerlings are stocked annually. As production of graylings requires special efforts, the stocked material is usually not of local origin. This results in extensive translocations, ignoring watersheds and biogeographical borders. Molecular studies demonstrate that there is still a remarkable diversity of graylings in Europe, even within heavily impacted central Europe. Nevertheless, the integrity of some populations may have been destroyed by stocking.

Further reading. Weiss et al., 2002 (genetics); Knizhin et al., 2004 (diversity); Froufe et al., 2005 (phylogeny); Gum et al., 2005 (phylogeny).

Thymallus arcticus

Common name. Siberian grayling.

Diagnosis. Distinguished from *T. thymallus* (sympatric in some rivers of northern Urals) by: ● maxilla reaching middle of eye / ● pelvic yellowish, with distinct red stripes / ● red spots on body / ● dorsal bluish violet, with several rows of irregular multicoloured spots in posterior part / ● gill rakers 14–22, averaging about 16–17. Size up to 450 mm SL and 1.9 kg.

Distribution. Arctic Ocean basin, in Siberia from Ob to Yenisei drainages, in Europe in some tributaries of Pechora (Usa, Kosyu, Kozhim), Korotaikha and Kara.

Habitat. Piedmont and montane cold streams, rivers and lakes with high oxygen concentrations. Spawns in montane streams with heavy current on shallows with rock-gravel bottom.

Biology. Migratory pattern and duration of the different stages of life cycle differ depending on habitat. Lives up to 10 years. Spawns for the first time at 3–4 years, earlier in small streams. Breeding

Thymallus arcticus; Pechora, Russia. V. I. Ponomarev

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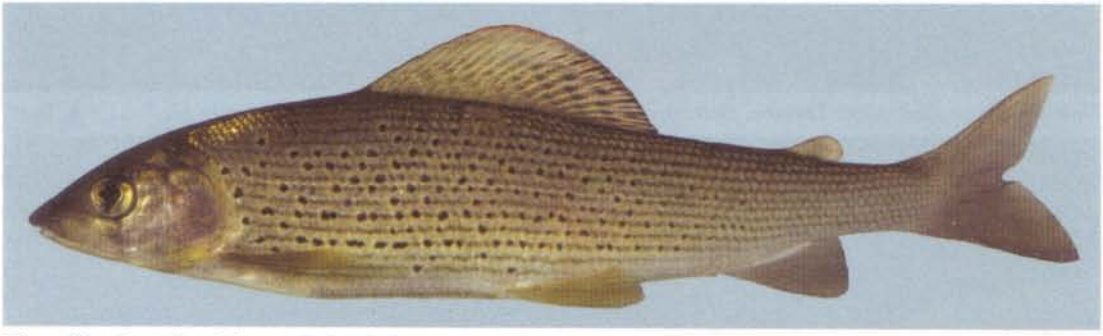
Thymallus thymallus; Doubs, Rhône drainage, Switzerland; 280 mm SL.



Thymallus thymallus; Lignon, Loire drainage, France; ~280 mm SL. H. Persat

males are brighter coloured and have an enlarged posterior part of dorsal. In April – May, migrates to upper reaches for foraging and spawning; in summer, returns downriver to larger streams and lakes, then, in winter, moves to deeper places. Spawns in May – June at 6–12°C. Embryonic development takes 10–14 days. Feeds on benthic organisms and small fish. Larvae and small juveniles feed on small crustaceans and other small objects, then up to 70 % of diet contains insect larvae, worms, molluscs, and terrestrial insects.

Conservation status. LC. Very sensitive to water quality, therefore vulnerable in places with industrial pollution.

Further reading. Zinoviev, 1976 (morphology), 1989 (morphology, ecology, distribution); Pivnička & Hensel, 1978 (morphology); Koskinen et al., 2002 (genetics); Kottelat, 2006: 23 (systematics).

Thymallus thymallus

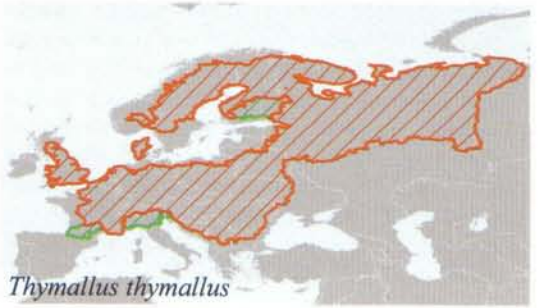
Common name. European grayling.

Diagnosis. Distinguished from *T. arcticus* by: ● maxilla usually reaching anterior margin of eye / ● pelvic grey, without red stripes / ● no red spots on body / ● dorsal greyish, with parallel rows of round dark spots / ● gill rakers 19–30, averaging about 24–26. Size up to 500 mm SL.

Distribution. Barents Sea basin west of Urals, Caspian, Black, Baltic, White and North Sea basins, Atlantic westward to Loire drainage; Rhône drainage; northern Adriatic basin east to Soca drainage. Introduced over most of southern and central Finland.

Habitat. Submontane reaches of rivers with a hard sand or stone bottom and well oxygenated, cold and fast-flowing water. In Scandinavia, in clear lakes and semi-anadromous in freshened part of northern Baltic basin. Usually in hollows behind

Thymallus arcticus



Thymallus thymallus

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Thymallus thymallus; upper Danube, Germany; courting pair, male in foreground; ~250 mm SL. A. Hartl

Thymallus thymallus; upper Danube, Germany; spawning group, female in foreground; ~250 mm SL. A. Hartl

boulders and shaded water under overhanging vegetation. Spawns in shallow stretches (usually 20–40 cm deep) or riffles, with moderate current (about 0.5 m/s) and clean gravel bottom.

Biology. Spawns for the first time at 2–3 years, females usually 1 year later than males, in northern Europe later than in central Europe. Spawns in early spring, usually in March – April, later in north, when temperatures reach 4–8°C, with a peak at full moon. Adults make short spawning migrations. Lacustrine populations often spawn in lake tributaries. Males start to defend small territories at spawning site in late morning and spawning usually starts in early afternoon at highest daily temperature. Females deposit eggs into substrate. Eggs hatch usually in 10–40 days. Alevins remain in gravel until yolk sack is absorbed (4–10 days). Feeding larvae live 3–4 weeks in open water below surface. Juveniles are benthic, in fast-flowing waters. Feeds predominantly on drifting invertebrates and terrestrial insects.

Conservation status. LC. Locally threatened.

Remarks. Another species, *T. baicalensis*, has been introduced to Czechia and Slovakia in 1959. It first established a breeding population, but it disappeared around 1975, reportedly as a result of hybridisation with the local *T. thymallus*.

Reported genetic variability suggests that at least the Adriatic and Loire populations are distinct lineages, potentially distinct species, but diagnostic morphological data are not yet available. Because of extensive stocking throughout the northern Adriatic basin it might be too late to investigate the original morphology, variability,

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Thymallus baicalensis; Selenge, Yenisei drainage, Mongolia. J. Schöffmann

genetics, and distribution of the Adriatic population.

Further reading. Dujmic, 1997 (biology); Surre et al., 1986 (morphology); Barus & Oliva, 1995a: 538, 1995b: 610 (biology, *T. baicalensis*); Persat, in Keith & Allardi, 2001: 260 (biology); Weiss et al., 2002 (genetics); Knizhin et al., 2006 (*T. baicalensis*).

Mures, Romania; habitat of *Thymallus thymallus*.

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Family Lotidae

Burbots

A small family of mostly marine fishes with 6 genera and about 21 species within the diverse order Gadiformes. They are widely distributed in cold seas of Arctic, Atlantic and Pacific Oceans. *Lota* is the only freshwater member of the family, distinguished from European marine genera by: one central barbel on lower jaw; two dorsal fins; one anal fin with 64–84½ total rays; body marbled dark brown; no prominent nasal barbel. The related cods of the genus *Gadus* (family Gadidae) occasionally may enter estuaries in Baltic, White and Barents Seas and perhaps also elsewhere. *Gadus* have 3 dorsal fins (vs. 2 in *Lota*). The earlier family Gadidae is now divided into the families Merlucciidae, Gadidae, Lotidae, Gaidropsaridae and Phycidae; the last three are considered to be subfamilies of Gadidae by some authors.

Further reading. Markle, 1989 (systematics); Cohen et al., 1990 (overview); Teletchea et al., 2006 (phylogeny).

Lota lota

Common name. Burbot.

Diagnosis. Distinguished from all other European freshwater fishes by: ● pelvic origin anterior to pectoral origin / ● one central barbel on lower jaw / ○ two dorsal fins / ○ 64–84½ total anal rays / ○ body dark brown, marbled. Size up to about 1000 mm SL and 24 kg.

Distribution. Europe: from Loire drainage (France) eastward to White, Barents and Arctic Sea basins; upper Volga drainage; western Caspian basin; rivers draining to Black Sea; Rhône drainage (France); in Italy, native only in Po drainage; eastern England (now extirpated). In Siberia eastward to River Lena. Originally absent from Iberian Peninsula, central and southern Italy, Adriatic basin, Greece, Ireland, western and northern Great Britain and western France.

Lota lota

Habitat. All well oxygenated flowing waters and large lakes. Known from estuaries of large lowland rivers as well as from small mountain streams. Prefers deep waters in summer.

Biology. Generally nocturnal. Males reproduce for the first time at 2 years, females at 3 in Central Europe. Spawns in November – March, at temperatures below 6°C. May undertake short spawning migrations. Spawns at night, in groups of up to 20 interlaced individuals forming a ball about 60 cm in diameter constantly moving and rolling on the bottom, releasing eggs and sperm. Eggs are semipelagic, slightly sticky and 1.2–1.8 mm in diameter. Eggs hatch after 40–70 days. Larvae are positively phototactic, float below surface in March – April. After about 2 months, juveniles are benthic, grow rapidly, reach about 80 mm SL within first year. Active during winter even below ice cover, temperature preference 11-13 C°. Less active and low food intake at temperatures above 20°C. Glycogene and fat are stored in liver during spring and autumn, serving as an energy reserve to survive physiological unsuitable high water temperatures, enableing even a certain length growth and gonad development during summer. Larvae feed on drifting invertebrates or zooplankton. Juveniles and adults feed on large invertebrates and small fish.

Conservation status. LC. Locally threatened by river regulation.

Remarks. The genus *Lota* is in a need of critical revision. Populations from eastern Siberia and North America represent a distinct species, *L. maculosa*.

Further reading. Hubbs & Schultz, 1941: 17 (systematics); Berg, 1949: 943 (systematics); Ryder & Pesendorfer, 1992 (biology); Gahn & Sprules, 1993 (biology); Hardewig et al., 2004 (physiology).

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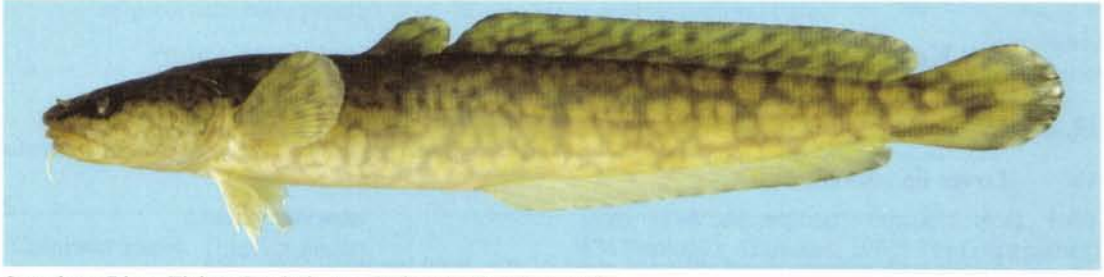
Lota lota; upper Danube, Germany; ~400 mm SL. A. Hartl

Lota lota; lower Odra, Germany; ~300 mm SL.



Lota lota; River Ticino, Po drainage, Switzerland; 175 mm SL.

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Family Mugilidae

Grey mullets

A family of 14 genera and about 65 species know mostly from tropical seas. A few species are known from temperate seas. Some inhabit freshwaters, but most are marine, coastal species, which occasionally enter lagoons, estuaries or lower reaches of rivers. Distinguished from superficially similar Atherinidae by head dorso-ventrally flattened (vs. laterally compressed); scales on dorsal surface of head (vs. absence); 11–14½ anal rays (vs. 10–20½). Mullets are pelagic fishes living in schools, usually in waters less than 200 m deep, and over mud bottom. They spawn at sea. Eggs and early larvae are pelagic, small juveniles move towards the shores and enter estuaries and lagoons where they feed on zooplankton. Larger individuals return to the sea where they feed on algae and vegetal detritus, usually taking a lot of sediment, which they filter with their branchial apparatus. All species are very similarly shaped, silvery and quite difficult to identify, especially on the basis of juveniles. Six native and one introduced species are recorded from European waters, of which only *Oedalechilus labeo* is not known definitely to enter fresh or inland waters.

Further reading. Bograd, 1961 (movements in freshwater); Thomson, 1997 (systematics).

Key to species of Mugilidae entering European freshwaters

1a – Lower ¼–⅓ of upper lip with 2–3 rows of papillae with horny ridges. ..... *Chelon labrosus*

1b – Lower lip smooth. 2

2a – Adults with adipose tissue covering most of eye, reaching pupil (Fig. 74a). ..... *Mugil cephalus*

2b – Adults with an adipose tissue rim around eye (Fig. 74b). 3

3a – Posterior extremity of upper jaw reaching beyond anterior rim of eye. ..... *Liza haematocheilus*

3b – Posterior extremity of upper jaw not reaching anterior rim of eye. 4

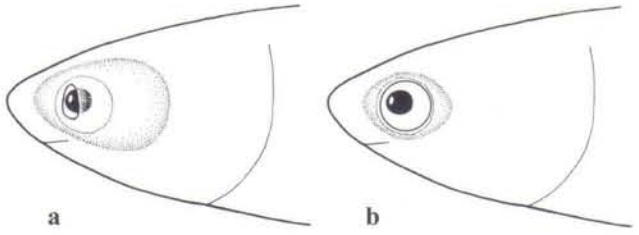

Figure 74 Adipose tissue around eye in Mugilidae: **a,** *Mugil cephalus*; **b,** *Liza* species.

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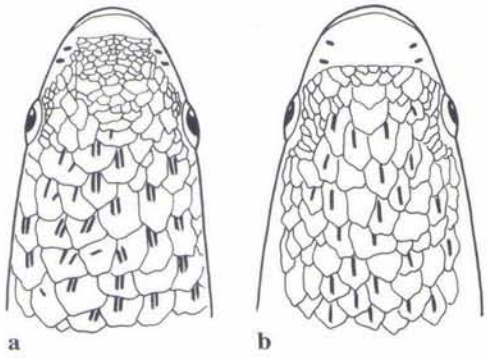

Figure 75 Longitudinal grooves on predorsal scales of *Liza* species. **a,** *L. saliens*; **b,** other species (after Svetovidov, 1964).

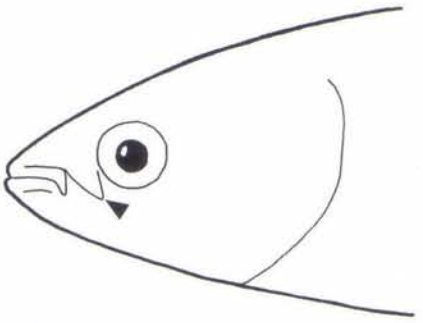

Figure 76 Head of *Liza aurata* showing pointed posterior angle of preorbital bone (arrow).

4a – Predorsal scales with 2–5 longitudinal grooves (Fig. 75a); 48–49 lateral line scales (not including scales on caudal base).
..... *Liza saliens*

4b – Predorsal scales with a single or no longitudinal groove (Fig. 75b); 40–46 lateral line scales (not including scales on caudal base).
..... 5

5a – 20 circumpeduncular scale rows; when folded forward, pectoral reaching eye; posterior angle of preorbital bone pointed (Fig. 76); no black spot at pectoral base.
..... *Liza aurata*

5b – 24 circumpeduncular scale rows; when folded forward, pectoral not reaching eye; posterior angle of preorbital bone rounded; a black spot at inner pectoral base.
..... *Liza ramada*

Chelon labrosus

Common name. Thicklip mullet.

Diagnosis. Distinguished from other species of Mugilidae in area by: ● lower ¼–⅓ of upper lip with 2–3 rows of papillae with horny ridges. Size up to 600 mm SL.

Distribution. Coasts of Mediterranean, Black Sea and Eastern Atlantic from Cape Verde and Senegal to southern Norway, southern Iceland and Faroe Islands.

Habitat. Pelagic near shores, sometimes in lagoons and estuaries. Spawns at sea in coastal surface water.

Biology. Usually lives in schools along shores, frequently enters lagoons and estuaries, juveniles easily adapt to freshwater. Lives up to 12 years. Males reproduce for the first time at 2 years, females at 3, later in northern areas. Females larger than males. Spawns pelagic eggs in February – April. Juveniles around 20 mm SL move to coastal lagoons and estuaries in April – June, return to sea in summer. Juveniles feed on zooplankton; adults feed on algae and vegetal detritus.

Conservation status. LC.

Further reading. Ben Tuvia, in Whitehead et al., 1986: 1198 (description); Gandolfi et al., 1991: 474 (biology); Thomson, 1997: 539 (systematics).

Liza aurata

Common name. Golden mullet.

Diagnosis. Distinguished from other species of *Liza* in Europe by: ● usually a golden blotch on opercle / ○ predorsal scales with a single or no longitudinal groove (Fig. 75b) / ○ 20 circumpeduncular scale rows / ○ when folded forward, pectoral reaching eye / ○ posterior angle of preorbital bone pointed (Fig. 76) / ○ 40–41 lateral line scales (not including scales on caudal base). Size

Chelon labrosus

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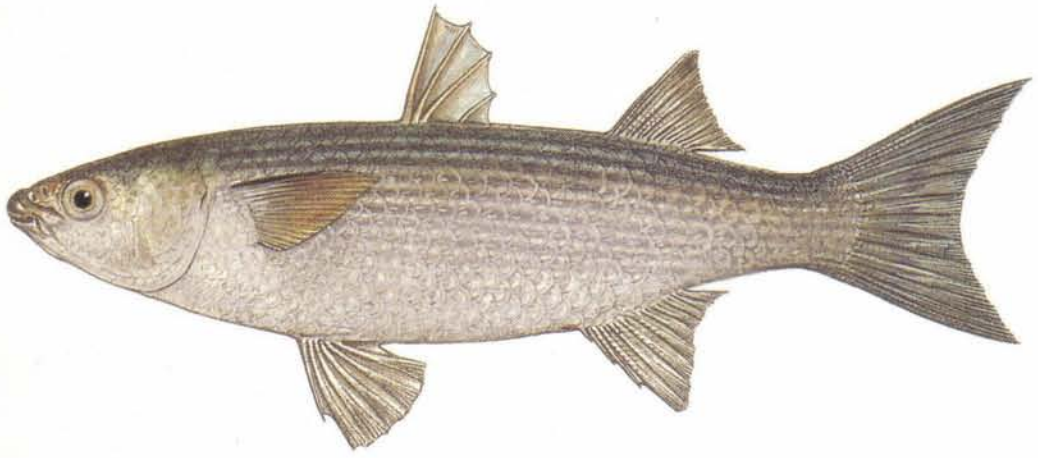
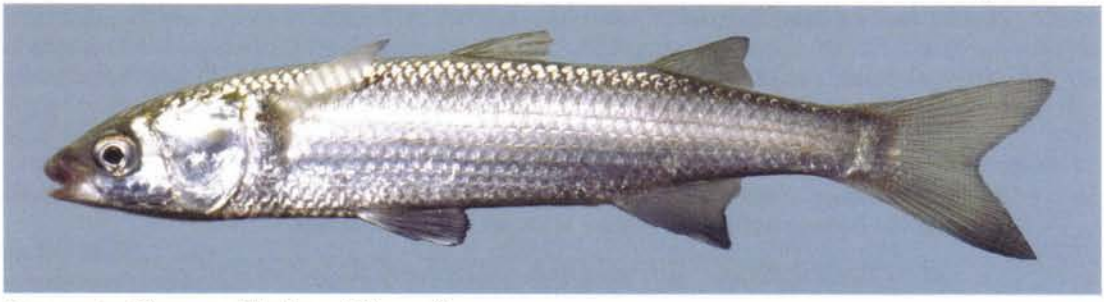


Chelon labrosus; Italy. (from Bonaparte, 1834)



Liza aurata; Chornaya, Ukraine; ~120 mm SL.

up to 500 mm SL.
Distribution. Mediterranean, Black Sea and Eastern Atlantic from Cape Verde and Senegal to southern Norway and British Isles (not reaching southern Baltic); northern Red Sea. Introduced in Caspian Sea.
Habitat. Pelagic near shore, sometimes in lagoons and estuaries, rarely into freshwaters. Among Mugilidae recorded from European freshwaters, this is the least tolerant of freshwater. Spawns at sea.
Biology. Usually lives in schools. Spawns in September – November. Juveniles move to coastal lagoons and estuaries in winter and especially in spring. Juveniles feed on zooplankton, larger individuals feed on algae and vegetal detritus.
Conservation status. LC.
Further reading. Ben Tuvia, in Whitehead et al., 1986: 1199 (description); Gandolfi et al., 1991: 465 (biology); Thomson, 1997: 517 (systematics).

Liza haematocheilus

Common name. Soiyu mullet.
Diagnosis. Distinguished from other species of *Liza* in Europe by: ● posterior extremity of upper jaw reaching beyond anterior rim of eye / ○ predorsal scales with a single longitudinal groove (Fig. 75b) / ○ 41–42 lateral line scales (not including scales on caudal base) / ○ 24 circumpeduncular scale rows. Size up to about 530 mm SL.
Distribution. Coast of East Asia from Vladivostok to Hainan Island. Introduced in Sea of Azov in late 1960s, reached Aegean Sea in 1995.
Habitat. At sea, pelagic near shore. Juveniles entering brackish waters of lagoons and lower reaches of rivers. Spawns at sea and in brackish limans. Enters freshwater to overwinter.
Biology. Juveniles spend their first year in freshwater, then migrate to sea. Detritivorous.
Conservation status. Alien. Invasive. In Azov Sea, it is now the most abundant mugilid species. Along shores of Black Sea, its expansion corresponds to a sharp decline of native species of Mugilidae, which it apparently replaces.
Remarks. Frequently called *Mugil soiuy* or *L. lauvergnii* in fisheries literature.
Further reading. Starushenko & Kazansky, 1996 (introduction); Thomson, 1997: 523 (systematics; as *L. lauvergnii*); Koutrakis & Economidis, 2000: 299 (biology).

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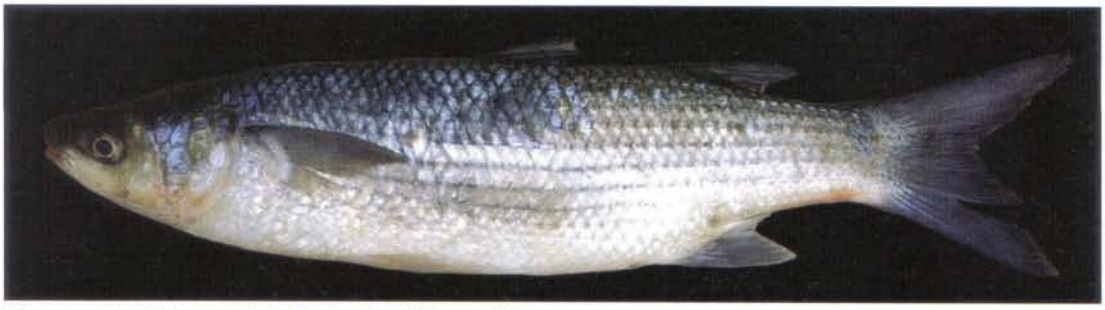
Liza haematocheilus; Azov Sea, Russia; ~100 mm SL.



Liza ramada; Lisboa market, Portugal; ~350 mm SL.

Liza ramada

Common name. Thinlip mullet.

Diagnosis. Distinguished from other species of *Liza* in Europe by: ○ predorsal scales with a single or no longitudinal groove (Fig. 75b) / ○ 24 circumpeduncular scale rows / ● when folded forward, pectoral not reaching eye / ○ posterior angle of preorbital bone rounded / ● a black spot at pectoral base / ○ 41–46 lateral line scales (not including scales on caudal base). Size up to 545 mm SL.

Distribution. Mediterranean, Black Sea, Azov Sea and Eastern Atlantic from Cape Verde and Senegal to southern Baltic and British Isles (not reaching northern Scotland). Migrates north during summer. Landlocked population in Fratel reservoir, Portugal. Introduced in Lake Kinneret (Israel).

Habitat. Pelagic near shore, entering lagoons and lower reaches of rivers, often found in polluted waters. Spawns offshore at sea.

Biology. Usually lives in schools. Males reproduce for the first time at 2–3 years, females at 4 or later. Females somewhat larger than males. Spawns several million pelagic eggs in September – December, April – July on British coast. Juveniles around 20 mm SL move to coastal lagoons and estuaries in autumn and especially winter. Juveniles feed on zooplankton until about 30 mm SL, then on benthic animals and plants. Adults filter algae and vegetal detritus.

Conservation status. LC.

Further reading. Ben Tuvia, in Whitehead et al., 1986: 1200 (description); Gandolfi et al., 1991: 461 (biology); Costa Pereira, 1995: 506; Thomson, 1997: 529 (systematics).

Liza saliens

Common name. Sharpnose mullet.

Diagnosis. Distinguished from other species of *Liza* in Europe by: ● predorsal scales with 2–5 longitudinal grooves (Fig. 75a) / ● 48–49 lateral line scales (not including scales on caudal base) /

Liza aurata

Liza ramada

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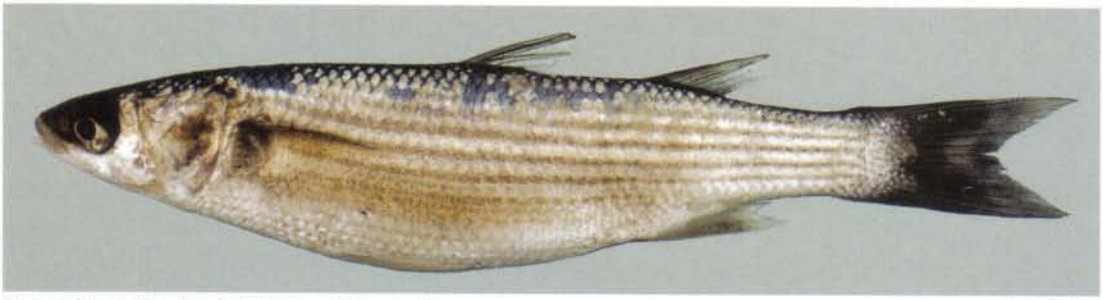
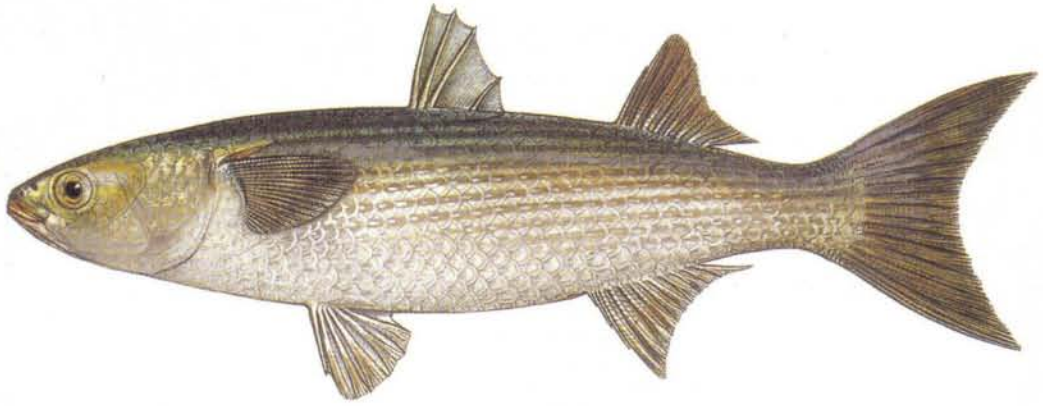


Liza saliens; Caspian Sea, Iran; ~130 mm SL. A. Abdoli



Mugil cephalus; Italy. (from Bonaparte, 1834)

O 20 circumpeduncular scale rows / O when folded forward, pectoral reaching eye. Size up to 350 mm SL.

Distribution. Mediterranean, Black Sea and Eastern Atlantic from Angola to Bay of Biscay. Introduced in Caspian Sea.

Habitat. Pelagic near shore, sometimes in lagoons and estuaries. Spawns at sea.

Biology. Usually lives in schools. Males reproduce for the first time at 2 years, females at 3. Females larger than males. Spawns pelagic eggs in May – August, rarely until early October. Juveniles around 20 mm SL move to coastal lagoons and estuaries in summer and autumn. Juveniles feed on zooplankton until about 30 mm SL, then on benthic organisms until 50 mm SL; adults feed on algae and vegetal detritus.

Conservation status. LC.

Further reading. Ben Tuvia, in Whitehead et al., 1986: 1201 (description); Gandolfi et al., 1991: 461 (biology); Thomson, 1997: 533 (systematics).

Mugil cephalus

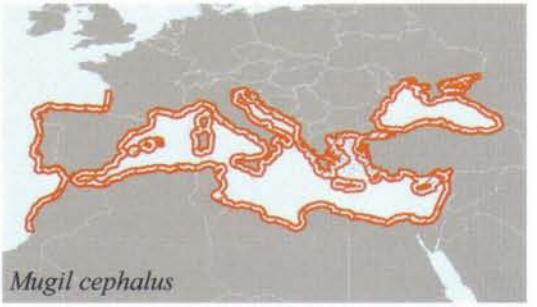
Common name. Striped mullet.

Diagnosis. Distinguished from other species of Mugilidae in Europe by: ● adipose tissue covering most of eye, reaching pupil in adults (Fig. 74a). Size up to about 800 mm SL.

Distribution. In all tropical and subtropical seas; Mediterranean, Black Sea and Atlantic, reaching northward to Bay of Biscay. Introduced in Lake Trasimeno (Italy) and possibly elsewhere.

Habitat. Pelagic near shores, sometimes forages in lagoons, estuaries and lower courses of rivers.

Liza saliens



Mugil cephalus

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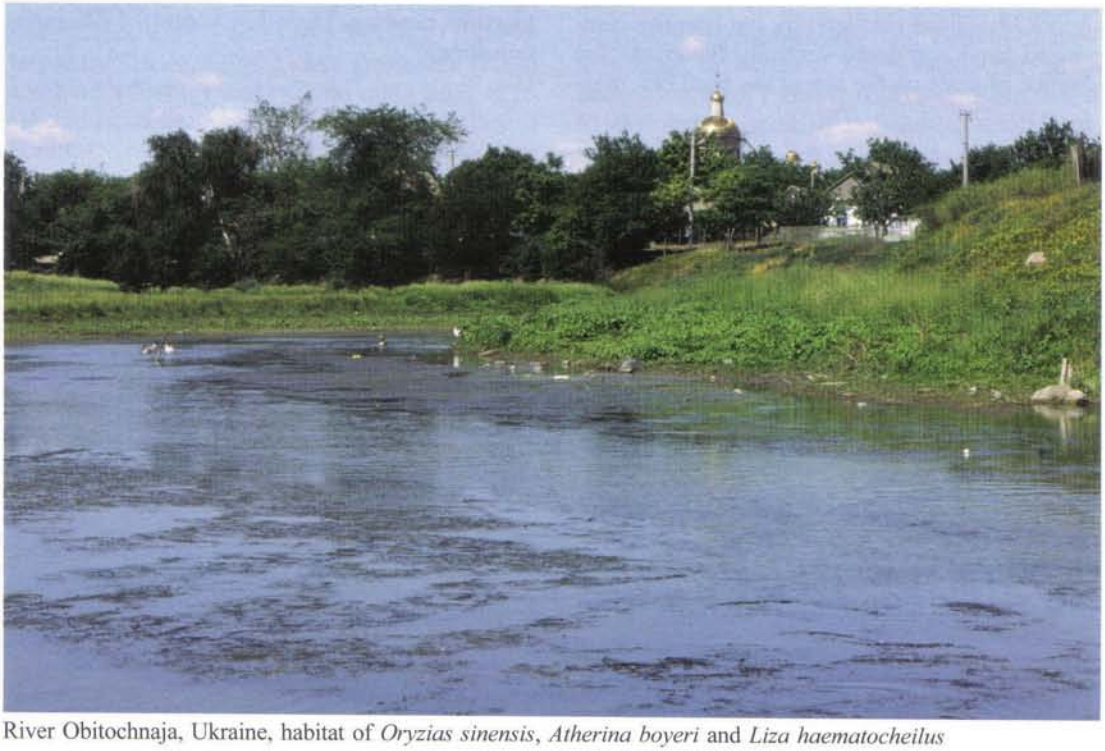
Spawns at sea in coastal surface water.
Biology. Usually lives in schools. Males reproduce for the first time at 2 years, females at 3. Females larger than males. Spawns several million of pelagic eggs in July – October. Eggs develop optimally at full marine salinity. Juveniles around 20 mm SL move to coastal lagoons and estuaries in autumn. Juveniles feed on zooplankton until about 30 mm SL, larger individuals filter algae, vegetal detritus and small invertebrates.
Conservation status. LC.
Further reading. Ben Tuvia, in Whitehead et al., 1986: 1202 (description); Gandolfi et al., 1991: 454 (biology); Thomson, 1997: 483 (systematics).



River Obitochnaja, Ukraine, habitat of *Oryzias sinensis*, *Atherina boyeri* and *Liza haematocheilus*

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Family Atherinidae

Silversides

A family of mostly small to medium euryhaline fishes with about 50 genera and 170 species found throughout the world's tropical and temperate seas; about 50 species are confined to freshwater and many enter brackish waters or coastal rivers. Atherinids are characterised by a silvery, elongate, compressed body, two widely separated dorsal fins, large eye, and a long snout with a terminal mouth. They are distinguished from superficially similar Mugilidae (mullets) by the laterally compressed head (vs. dorso-ventrally flattened), the absence of scale on the top of the head (vs. presence), 10–20½ anal rays (vs. 11–14½). Atherinids school and are often very abundant in estuarine ecosystems. They are stocked and intensively fished, especially around the Mediterranean. A single species is known to enter European freshwaters (the taxonomy of the family is, however, still far from well resolved). The key below should facilitate the identification of the native coastal and freshwater species of *Atherina* in Europe.

Further reading. Dyer & Chernoff, 1996 (relationships).

Key to species of Atherinidae in Europe

1a – 59–65 total scales in midlateral series; 10–12½ anal rays. ..... *Atherina hepsetus*

1b – 39–57 total scales in midlateral series; 13–17½ anal rays 2

2a – 52–57 total scales in midlateral series. ..... *Atherina presbyter*

2b – 39–49 total scales in midlateral series. 3

3a – 23–31 gill rakers; freshwater or estuarine. ..... *Atherina boyeri*

3b – 33–41 gill rakers; marine. ..... *Atherina mochon*

Atherina boyeri

Atherina boyeri

Common name. Sand smelt.

Diagnosis. Distinguished from other species of Atherinidae in Europe by: ○ 39–49 total scales in midlateral series / ○ 23–31 gill rakers / ○ 13–15½ anal rays. Size up to about 85 mm SL, 120 mm in Lake Trichonis and 145 mm in Caspian Sea.

Distribution. Along coasts of Mediterranean, Black, Azov and Caspian Sea basins. Atlantic coast northward to Loire estuary (France). Isolated populations along coasts of southern England and the Netherlands (some might actually be the marine *A. mochon*). Permanent freshwater resident populations in Guadalquivir and Tagus (now extirpat-

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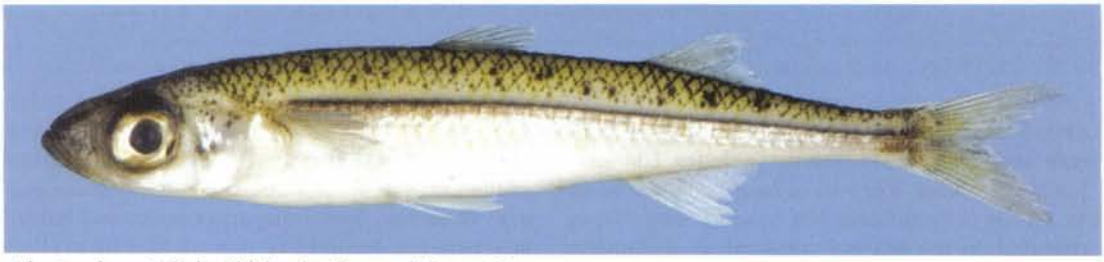
Atherina boyeri; Lake Trasimeno, Italy; ~70 mm SL.



Atherina boyeri; Lake Trichonis, Greece; 76 mm SL.

ed) drainages, Santo André lagoon (Portugal) and Lakes Trichonis (Greece) and Sapanca (Turkey). Introduced in Aral Sea, Lakes Trasimeno (Italy) and Iznik (Turkey), and perhaps other lakes in Italy and Anatolia.

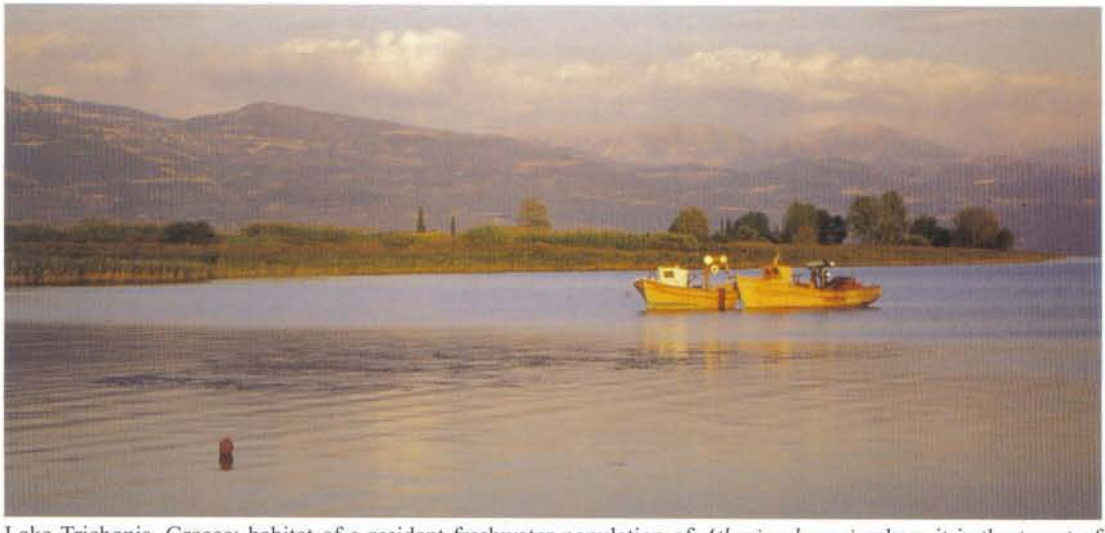
Habitat. Lower parts of rivers, estuaries, coastal lakes and sea. Freshwater populations prefer still or slow-flowing waters. Pelagic in lakes.

Biology. Gregarious. Usually lives 1–2 years, rarely up to 4. Spawns for the first time at 1–2 years. Freshwater populations spawn in April – June in Guadalquivir, in March – October in Lake Trichonis. Short spawning migrations into estuaries in some populations. Fractional spawner, larger individuals spawn for a longer period. Eggs with long hairy appendages attaching them to filamentous algae, deposited at 2–6 m depth. Larvae are pelagic but often form schools close to the shores. In lakes and estuaries, feeds mainly on small planktonic invertebrates, often on benthos in rivers.

Conservation status. LC.

Remarks. *A. lagunae* is an invalid name.

Further reading. Whitehead et al., 1986: 1208 (diagnosis; in part); Economou et al., 1994a: 30 (larvae); Kottelat, 1997: 159 (nomenclature); Daoulas et al., 1997 (larvae); Leonardos & Sinis, 2000: 81 (biology); Leonardos, 2001 (ecology); Miller, 2003 (biology).



Lake Trichonis, Greece; habitat of a resident freshwater population of *Atherina boyeri*, where it is the target of commercial fishery.

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Family Atherinopsidae

Neotropical silversides

Atherinopsidae are silversides that inhabit tropical and subtropical waters of South America, both fresh and marine. The family includes 104 species in 13 genera. They have long been placed in the family Atherinidae, but have recently been separated on the basis of anatomical characters. One species has been introduced to European waters and is traditionally identified as *Odonthestes bonariensis*; as this identification dates back to the seventies and as many changes have since taken place in the systematics of Neotropical silversides, the species' name may be incorrect.

Further reading. Dyer, in Reis et al., 2001 (diversity).

Odonthestes bonariensis

Common name. La Plata silverside.

Diagnosis. Only species of Atherinopsidae in European waters. Distinguished from native European Atherinidae by: ● 15–20½ anal rays (vs. 10–17½) / ● first dorsal origin almost above anus (vs. clearly in front) / ● rays of first dorsal much shorter than rays of second dorsal (vs. as long or longer) / ● second dorsal origin above second half of anal base (vs. behind anal origin). Size up to about 520 mm SL.

Distribution. Native to La Plata, lower Parana, Uruguay and Tramandai drainages and Laguna de los Patos (Argentina, Brazil, Uruguay). Introduced in 1974 in Lake Nemi (Italy).

Habitat. Coastal lagoons and near estuaries, usually in freshwater.

Biology. Gregarious. Lives up to 4 years. Spawns for the first time at 1–2 years. Spawns in March – October in Lake Nemi. Eggs are deposited among aquatic vegetation. Feeds on zooplankton.

Conservation status. Alien.

Further reading. Malabarba & Dyer, 2002 (diagnosis); Miller, 2003 (biology).

Odonthestes bonariensis; Brazil; 330 mm SL. L. Malabarba

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Key to species of Adrianichthyidae, Fundulidae, Poeciliidae, Valenciidae and Cyprinodontidae in Europe

All these families had formerly been placed in the family Cyprinodontidae. They are now considered distinct, with the Adrianichthyidae in the order Beloniformes and the four others in the order Cyprinodontiformes. We give a common key to the species of these five families because there is still much confusion about them, especially between the native species and some of the introduced ones.

1a – Anal of male modified into an intromitent organ (gonopodium; Fig. 77); adult female with a dark blotch above and slightly in front of anal (Fig. 77b).
..... 2

1b – Anal of male not modified into an intromitent organ; adult female without dark blotch above and slightly in front of anal.
..... 3

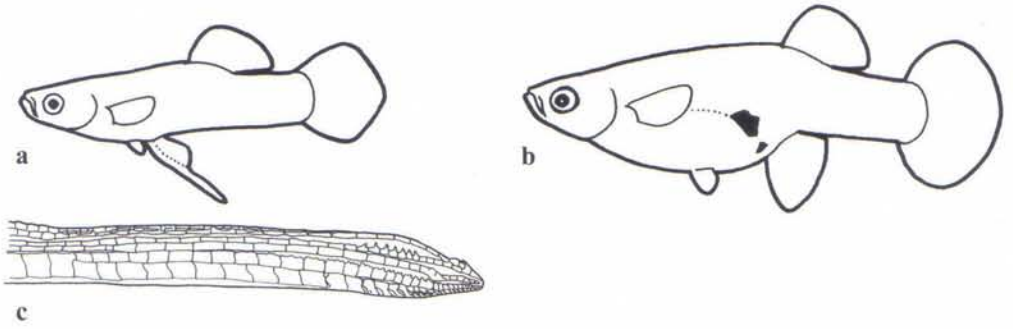

Figure 77 Schematised poeciliid showing sexual dimorphism in anal fin shape of male (**a**) and female (**b**), and modified anal rays of male (gonopodium, **c**) (**c** after Berg, 1949).

2a – Male plain dull grey; both sexes with rows of black spots in dorsal and caudal.
..... *Gambusia holbrooki*

2b – Male brightly coloured in life, with black spots on flank in preserved individuals.
..... *Poecilia reticulata*

3a – Anal with 16–20 total rays; dorsal with 5–7 total rays, its origin behind mid-length of anal base; length of anal base more than twice length of dorsal base; body plain brownish in both sexes.
..... *Oryzias sinensis*

3b – Anal with 9–15 total rays; dorsal with 8–15 total rays, its origin in front of, above or slightly behind anal origin; length of anal base less than twice length of dorsal base; body with dark bars or spots in both sexes.
..... 4

4a – 32–37 scales in midlateral series on body; 16–21 pectoral rays.
..... *Fundulus heteroclitus*

4b – 23–32 scales in midlateral series on body; 9–16 pectoral rays.
..... 5

5a – Dorsal origin behind or above anal origin; teeth unicuspid and conical.
..... 6

5b – Dorsal origin in front of anal origin; teeth tricuspid.
..... 7

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6a – Males with numerous very narrow dark bars on flank, not always distinct anteriorly, without iridescent spots on body; males with caudal yellow to orange, with reddish-brown posterior margin and spots organised into vertical rows; dorsal and anal of adult males reaching caudal; usually 12–13½ anal rays (coastal areas of eastern Spain).
..... *Valencia hispanica*

6b – Males with 10–14 dark bars somewhat narrower than or equal to interspaces, not always distinct anteriorly, with iridescent spots; males with caudal hyaline to bluish, with or without dark posterior margin, with spots organised into 2–4 vertical rows; dorsal and anal of adult males not reaching caudal; usually 11½ anal rays (western coast of Greece and Albania).
..... *Valencia letourneuxi*

7a – Caudal of male yellow to yellow-orange, sometimes with a wide dark submarginal band or a dark grey distal band; female with a midlateral row of small dark brown blotches or short bars on sides, sometimes with a few additional spots, and mottled back.
..... 8

7b – Caudal of male hyaline to bluish or dark-grey, with 2–5 dark grey bars; female with numerous dark brown spots on sides and back.
..... 9

8a – Female with 7–11 dark, roundish blotches on side, more or less connected by an irregular dark midlateral stripe; male with 6–11 dark bars on body (Greece: Peloponnese).
..... *Aphanius almiriensis*

8b – Female with 11–17 narrow dark bars on side, over a faint greyish midlateral stripe; male with 8–15 dark bars on body.
..... *Aphanius fasciatus*

9a – Caudal of male hyaline to bluish-grey, with 2–5 dark grey bars; female with numerous dark brown spots on side and back; usually 7–8½ anal rays.
..... *Aphanius iberus*

9b – Caudal of male dark grey, with one distinct submarginal bar and 4–5 vertical rows of hyaline dots sometimes organised in regular bars; female with few large black spots on side, usually organised in two rows, one on middle of flank, one on level of pectoral base; usually 9½ anal rays.
..... *Aphanius baeticus*

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Family Adrianichthyidae

Ricefishes

A small family with three genera, native to Asia, from Sri Lanka in the west to Timor in the southeast and Korea and Japan in the northeast. They are found primarily in freshwater, but a few species inhabit brackish waters, mangrove swamps and estuaries. They normally form small schools near the surface where they feed on insects. They have a small size (between 12 and 200 mm SL), a flat dorsal profile; the dorsal fin is small and pushed backward very close to the caudal-fin base, the anal fin has 14–25 rays. The body is usually dull brownish with a brilliant blue eye. Males usually have a darker body and fins (black in some species), two median purple stripes in the caudal fin, and elongated or filamentous rays in anal and dorsal fins. The female carries a cluster of a few eggs hanging by filaments from the genital opening. In the genus *Oryzias*, these egg clusters are deposited among the vegetation after a few days. In the genera *Adrianichthys* and *Xenopoecilus*, from the lakes of Sulawesi, the eggs are carried protected in a body cavity by the pelvics, until they hatch. Most of the species exhibit some sexual dimorphism, with the male having brighter colours and filaments on its dorsal and anal fins. Species of the genus *Oryzias* were earlier considered to represent a distinct family (Oryziidae).

O. latipes is a species much used for a variety of laboratory experiments and research, especially in Japan. In 1994, it was the first vertebrate to mate in space, in the space shuttle Columbia.

Further reading. Yamamoto, 1975 (biology); Rosen & Parenti, 1981 (phylogeny); Uwa & Parenti, 1988 (systematics, chromosomes); Kottelat, 1990a–b (Sulawesi species); Iwamatsu, 1993 (biology); Ijiri, 1995 (reproduction); Ozato, 1995 (ontogeny); Naruse, 1996 (phylogeny); Takehana et al., 2005 (phylogeny).

Oryzias sinensis

Common name. Chinese medaka.

Diagnosis. Distinguished from species of Atherinidae, Poeciliidae, Fundulidae, Valenciidae and Cyprinodontidae in Europe by: ● length of anal base more than twice length of dorsal base / ● dorsal origin behind mid-length of anal base / ○ body plain brownish in both sexes / ● blue eye. Size up to 31 mm SL.

Distribution. Native to East Asia, from Korea to Laos and Vietnam. Accidentally (?) introduced with larvae of Cyprinidae in 1971 in Kazakhstan where now abundant. Intentionally introduced for mosquito control in 1974 in lower Kuban drainage (Sea of Azov basin) and lakes of Anapka drainage (Black Sea basin). Established in lower Kuban drainage. Spreading in Azov basin, discovered in River Obitochnaya in 2003.

Habitat. Swamps, marshes, rice fields, backwaters, streams stretches with stagnant water and dense vegetation.

Oryzias sinensis; Kuban delta, Russia; ~20 mm SL.

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Biology. Lives about 1 year. Matures at 3 months. Spawns in April – September, when temperature rises above 26°C. Every few days, females spawn early morning a cluster of 15–50 eggs and carry them for a few hours, until they get entangled into aquatic vegetation by the filaments, which cover them. Eggs hatch in 10–12 days at 24°C. Tolerates temperatures from 0 to 42°C; survives winter under ice. Feeds on small invertebrates.

Conservation status. Alien. Expanding in areas where it is introduced, but regressing in most of its original range in Asia because of habitat modification and increased use of pesticides in rice fields.

Remarks. Usually identified as *O. latipes* but morphological and genetic data show that at least 2 species are involved. *O. latipes* is restricted to Japan and southernmost Korea.

Further reading. Abdildayev & Dubitskiy, 1974 (introduction); Sakaizumi & Jeon, 1987 (genetics); Chen et al., 1989 (systematics); Kim & Lee, 1992 (description, chromosomes); Kim, 1997: 379 (systematics, ontogeny); Kottelat, 2001a: 56 (systematics).

Waterfall on Jägala (a coastal blackwater stream), Estonia.

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Family Fundulidae

Killifishes, topminnows

Members of the family Fundulidae were formerly part of Cyprinodontidae, but as presently understood the family includes only five genera and about 50 species in North and Central America. They are characterized by having a single dorsal fin with soft rays, a truncate caudal fin, no lateral line, and the head and body usually covered by large cycloid scales. Most species have a sexually dimorphic colour pattern. Most are small, with the largest known about 180 mm SL. They typically inhabit the calm margins of streams, rivers, lakes and estuaries, in fresh and brackish waters.

Further reading. Wiley, 1986; Wildekamp, 1996.

Fundulus heteroclitus

Common name. Mummichog.

Diagnosis. Distinguished from species of Cyprinodontidae and Valenciidae in Europe by: ● male blue to olive, with narrow paler bars and silvery spots, especially posteriorly / ● 32–37 scales in

Fundulus heteroclitus; Guadiana delta, Portugal; male. R. Wildekamp

Fundulus heteroclitus; Guadiana delta, Portugal; female. R. Wildekamp

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midlateral series on body / ● 16–21 pectoral rays. Size up to about 100 mm SL.

Distribution. Native to North America from southern Québec to northeastern Florida. Introduced to southern Portugal and along Atlantic shore of southern Spain. Range presently expanding.

Habitat. In fresh, marine and hypersaline waters.

Biology. Gregarious. Lives up to 4 years. Reaches sexual maturity at about 35 mm SL and 1 year. Spawns in April – June in European waters. Eggs are spawned one by one, adhere to vegetation by filaments and hatch in 12–14 days. Feeds mainly on insect larvae and microcrustaceans.

Conservation status. Alien. Responsible for the decline of native species and the near extinction of *Aphanius baeticus* in southwestern Spain.

Remarks. This species had been known as *Valencia lozanoi*.

Further reading. Relyea, 1983: 5 (description); Fernández-Delgado et al., 1986 (synonymy); Bianco & Miller, 1989 (systematics); Wildekamp, 1996: 260 (biology); Doadrio, 2001: 235 (distribution).

Slow creek in Sperchios drainage, Greece; habitat of *Pungitius hellenicus*, *Gasterosteus* sp. and *Pelasgus marathonicus*.

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Family Valenciidae

Valencias

This family includes only 2 species with very restricted distributions, one along the eastern coast of Spain and one along the western coast of Greece and Albania. They were formerly included in Cyprinodontidae but are now considered as a distinct family on the basis of osteological characters. Superficially, they are distinguished by having the dorsal-fin origin behind or above the anal-fin origin, the teeth unicuspid and conical, 28–30 scales in midlateral series on body, and a less striking sexual dichromatism. Both sexes have basically the same colour pattern, but the pattern is more contrasted and the colours brighter in the males.
Further reading. Parenti, 1981.

Valencia hispanica

Common names. Samaruc, Spanish valencia.
Diagnosis. Distinguished from other species of Valenciidae, Fundulidae and Cyprinodontidae in Europe by: ♂ male bluish to greyish, with numerous very narrow darker bars, not always distinct anteriorly, without iridescent spots / ♀ male with caudal yellow to orange, with reddish-brown posterior margin, and spots organised into 4–7 verti-

Valencia hispanica; Peniscola, Spain; male. R. Wildekamp

Valencia hispanica; Peniscola, Spain; female. R. Wildekamp

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Valencia letourneuxi; Corfu, Greece; male, ~20 mm SL. A. Hartl

Valencia letourneuxi; Corfu, Greece; female. R. Wildekamp

cal rows / ● dorsal and anal of adult male reaching caudal / ○ 28–29 scales in midlateral series on body / ○ usually 12–13½ anal rays / ○ 13–14 pectoral rays. Size up to about 70 mm SL.

Distribution. Spain, along Mediterranean coast, between Tortosa and Cape San Antonio. Historical record from near Perpignan (France) where it is extirpated.

Habitat. Swamps, canals and freshwater lagoons, rarely in brackish water.

Biology. Lives up to 4 years. Spawns in April – July, lays portions of 10–30 eggs, which adhere to aquatic vegetation. Feeds mainly on crustaceans and insect larvae.

Conservation status. CR A2ace. Populations are declining, mainly because of habitat modifications and competition with the introduced *Gambusia holbrooki*.

Further reading. Planelles & Reyna, 1996 (conservation); Planelles-Gomis, 1999 (conservation); Caiola et al., 2001: 237 (biology).

Valencia letourneuxi

Common names. Zournas, Greek valencia.

Diagnosis. Distinguished from other species of Valenciidae, Fundulidae and Cyprinodontidae in Europe by: ○ male bluish to greyish, with 10–14 darker bars narrower than or as wide as interspaces, not always distinct anteriorly, with iridescent spots / ○ male with caudal hyaline to bluish, with

Valencia hispanica

Valencia letourneuxi

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or without dark posterior margin, and spots organised into 2–4 vertical rows / ♀ dorsal and anal of adult male not reaching caudal / ♀ 28–30 scales in midlateral series on body / ♀ usually 11½ anal rays / ♀ 12–14 pectoral rays. Size up to about 70 mm SL.

Distribution. Albania and western Greece, from Lake Butrint to Alfios drainages, and Corfu and Lefkas islands where it has apparently been extirpated.

Habitat. Swamps and clean, almost stagnant freshwater, with dense vegetation; usually associated with springs. Tolerates salinity (up to 4 ‰ in the wild, 46 ‰ in laboratory conditions) but prefers freshwater.

Biology. Lives up to 3 years. Spawns at least from April to August. Serial spawner. Deposits adhesive eggs about 2 mm in diameter on aquatic vegetation, probably a few every day. Feeds mainly on insects (especially chironomids).

Conservation status. CR A3ce; B2ab(i,ii,iii,iv,v). Populations are declining, mainly because of habitat modifications (especially water abstraction, drainage and irregular releases from reservoirs) and competition with and aggression by the introduced *Gambusia holbrooki*.

Further reading. Villwock et al., 1982 (diagnosis, genetics); Bianco & Miller, 1989 (habitat, diagnosis); Barbieri et al., 2000 (conservation, larvae, morphology), 2002b (conservation).

Lower Acheron, Greece; habitat of *Valencia letourneuxi*, *Knipowitschia milleri*, *Anguilla anguilla*, *Gasterosteus* sp. and *Pelasgus thesproticus*.

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Family Poeciliidae

Livebearers, poeciliids

A large family of small, fresh- and brackish-water fishes known from the Americas (from southern U.S.A. to Argentina) and Africa (south of the Sahara). Despite the name given to the family (livebearers), the African species are oviparous. The American species give birth to live young. They exhibit a striking sexual dimorphism. Females are usually larger and deeper bodied than males. The male has the anal fin modified into an intromitent organ (gonopodium; Fig. 77) through which sperm is introduced into the female's body. Fertilisation is internal. Females store the sperm, which can be used to fertilises several successive broods. The eyes of the embryos are usually visible as a dark blotch through the female's belly, immediately in front of and above the anal fin.

One species, the guppy *Poecilia reticulata*, is one of the world's most popular aquarium fishes and has escaped or been introduced in rivers and lakes throughout the tropics. It can be found in temperate regions where water is artificially warmed by water-cooled power stations. Guppies and mosquitofishes *Gambusia holbrooki* are often introduced in the hope that they might turn out to be beneficial by preying on mosquito larvae. However, worldwide, poeciliid introductions for mosquito control have had only marginal effects (if any) on mosquitoes, and negative to perhaps neutral impacts on native fishes. There is no justification to the introduction programs, which are still on-going in some countries. Mosquitofishes have been identified as the main or one of the main causes of the critical decline or extirpation of several populations of all European species of *Valencia* and *Aphanius*.

A number of species of Poeciliidae are in the aquarium-fish trade and some have occasionally been recorded in European waters, especially in the warm effluents of power plants. They disappear as soon as water temperature decreases and none has established. The most frequent ones are swordtails (*Xiphophorus helleri*), platies (*X. maculatus*) and black mollies (*Poecilia sphenops*).

Further reading. Meyer et al., 1985; Meffe & Snelson, 1989; Miller, 2005.

Gambusia holbrooki

Common name. Eastern mosquitofish.

Diagnosis. Distinguished from other species of Poeciliidae introduced to Europe by: ● male dull grey / ● both sexes with rows of black spots in dorsal and caudal. Size up to 30 mm SL in males, 55 mm in females.

Distribution. Native to North America, from Delaware drainage to Florida and Alabama. Introduced worldwide; established throughout southern Europe. Atlantic coast of France north to Loire estuary. Locally in southern Caspian basin and coastal areas of Black Sea basin. Introduced worldwide in tropical and subtropical countries.

Habitat. Still or slow-flowing waters. Prefers waters with dense aquatic vegetation. May survive in very polluted waters by taking oxygen from uppermost water layers.

Biology. Lives immediately under surface, catching prey at or under surface. Breeds in April – October (depending on latitude). Matures at 4–6 weeks, which means that 3 generations can be pro-

Xiphophorus helleri; Mexico; wild form, aquarium population. K. Yamazaki

Xiphophorus helleri; aquarium population. K. Yamazaki

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Gambusia holbrooki, Camargue, France; male, ~18 mm SL.

Gambusia holbrooki; Lake Doiran basin, Greece; female, 41 mm SL.

duced in one year. Gestation lasts 3–4 weeks. Brood may reach up to 354 young, but is generally around 40–60. Sexual activity ceases when temperature falls below 18°C. Feeds mainly on small aquatic invertebrates.

Conservation status. Alien. Introduction to Europe started in Spain (1921) by health authorities in the hope that it would control mosquitoes (vectors of various diseases). There is no evidence that it has had any impact on mosquitoes, but evidence is accumulating that it had an impact on native fishes, seriously threatening many endemic species, in Europe most notably *Aphanius iberus*, *A. baeticus*, *Valencia hispanica* and *V. letourneuxi*.

Remarks. Usually called *G. affinis* in the literature, a species identified by details of the gonopodium morphology, 5½ dorsal rays (vs. 6½ in *G. holbrooki*) and 8½ anal rays (vs. 9½). There is no confirmed record of the presence of true *G. affinis* in Europe.

Further reading. Wooten et al., 1988 (genetics); Rauchenberger, 1989 (phylogeny); Jenkins & Burkhead, 1993: 618 (biology); Doadrio, 2001: 240 (biology).

Poecilia reticulata; Venezuela; wild form, aquarium population; males. K. Yamazaki

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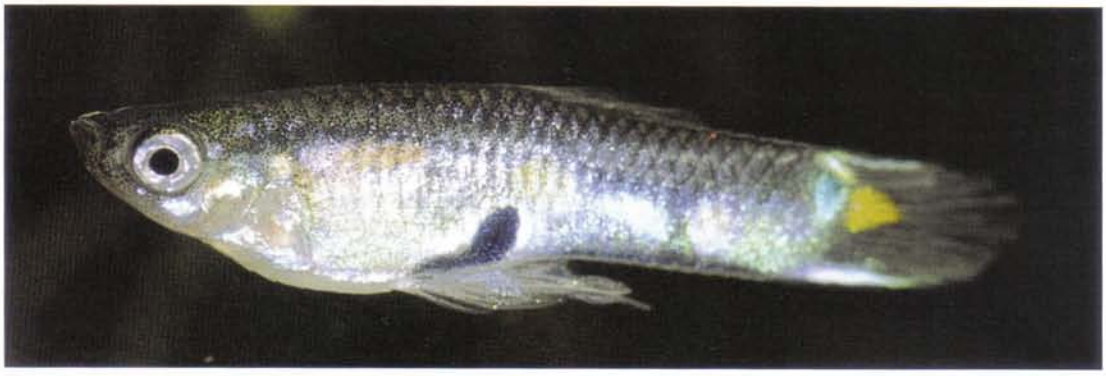

Poecilia reticulata; Oradea, Romania; male, ~15 mm SL.

Poecilia reticulata; Oradea, Romania; female, ~20 mm SL.

Poecilia reticulata

Common name. Guppy.

Diagnosis. Distinguished from other species of Poeciliidae introduced to Europe by: ● brightly coloured male in life, with black spots on flank in preserved individuals; there are various cultivated colour forms. Size up to 35 mm SL in males, 50 mm SL in females.

Distribution. Native to Venezuela, Guyana and adjacent islands. Introduced worldwide. Established in Mijares drainage (Spain). Populations have also become established in many hot springs in Hungary and Romania and, at least temporarily, in warm effluents of power plants in many countries (e.g. England, Netherlands, Germany, Russia).

Habitat. A wide variety of habitats with low predation pressure. Usually in very small streams and densely vegetated lakes and springs.

Biology. Unstudied in European populations. Females mature at about 3 months, males slightly earlier. Continuous, non-resource based and non-territorial mating system. Sexually dimorphic. Males brightly coloured and highly polymorphic, usually in the size range 14–17 mm SL. Females cryptically coloured, often exceeding 20 mm SL. Predation seems to be the main evolutionary pressure influencing colour patterns, life history traits and behaviour. *P. reticulata* is used extensively as a model in biology, especially for investigating evolution in the wild.

Conservation status. Alien.

Further reading. Haskins et al., 1961 (ecology); Liley & Seghers, 1975 (behaviour); Reznik et al., 1990 (biology); Magurran et al., 1995 (behaviour); Houde, 1997 (reproduction).

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Family Cyprinodontidae

Toothcarps

The definition, limits, and contents of the family Cyprinodontidae has been changing much in the past 30 years, from a large family, which included most killifishes (Rivulidae, Fundulidae, Valenciidae, etc.) to a much more restricted one. As presently understood, the family Cyprinodontidae includes two subfamilies, the Cubanichthyinae (with two species of *Cubanichthys*, endemic to Cuba and Jamaica) and the Cyprinodontinae, itself divided into 2 tribes, Cyprinodontini with 5 genera (from southern U.S.A. to Venezuela) and Orestiini. Orestiini seems a very strange assemblage with, on the one hand, *Orestias* (a genus know from high altitude lakes of the Andes, especially Lake Titicaca) and, on the other, the mainly peri-Mediterranean *Aphanius*. This is a quite astonishing biogeographical pattern and more changes in the systematics of these lineages would not be unexpected.

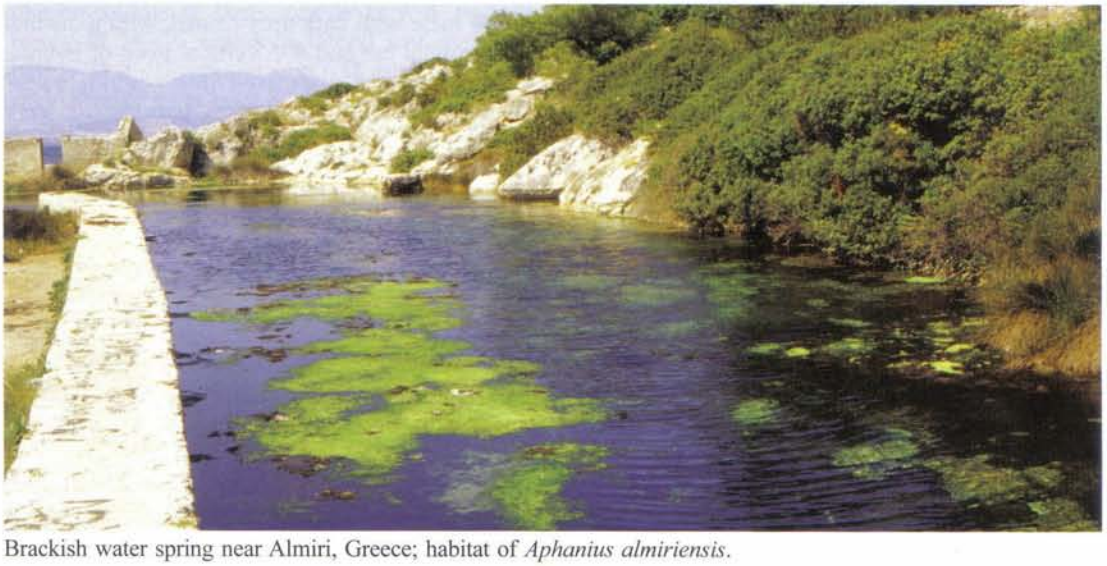
Species of *Aphanius* inhabit coastal waters of the Mediterranean, the Red Sea and the Persian Gulf, and inland waters (mostly springs, swamps or lakes with warm water and saline to hypersaline conditions) in Turkey, North Africa, Jordan Valley and Iran. To survive in these habitats, they are quite hardy fishes. Many of them are also able to live in freshwater, but given that they are quite poor competitors, only if true freshwater fishes are absent. This probably explains why many *Aphanius* populations and species have been much reduced or even rendered extinct following the introduction of exotic species, especially *Gambusia holbrooki*. About 20 *Aphanius* species are presently recognized. Their diversity is obviously underestimated and the status of numerous populations needs to be re-evaluated. The name *Aphanius* has sometimes been replaced by *Lebias*, but the latter name is incorrect. This has been confirmed by the International Commission on Zoological Nomenclature.

Further reading. Parenti, 1981 (phylogeny); Wildekamp, 1993 (systematics); Kottelat & Wheeler, 2001 (nomenclature); Hrbek & Meyer, 2003 (phylogeny); International Commission on Zoological Nomenclature, 2003 (nomenclature).

Aphanius almiriensis

Common name. Almiri toothcarp.

Diagnosis. Distinguished from other species of *Aphanius*, Valenciidae and Fundulidae in Europe



Brackish water spring near Almiri, Greece; habitat of *Aphanius almiriensis*.

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Aphanius almiriensis; Almiri, Greece; male, 30 mm SL.

Aphanius almiriensis; Almiri, Greece; female, 26 mm SL.

by: ○ male with yellow caudal, with a wide faint dark margin / ○ male with 6–11 (usually 6–8) dark bars on body, bars usually broad, regularly shaped and set / ● female with 7–11 dark, roundish blotches on side, more or less connected by an irregular dark midlateral stripe / ○ 25–28 scales in midlateral series on body / ○ 15–16 pectoral rays. Size up to about 31 mm SL.

Distribution. Greece: two springs, near Almiri and Meligou (Peloponnese).

Habitat. Fresh and brackish water springs (up to 23 ‰ salinity).

Biology. Observed in areas with slow current.

Conservation status. CR B1ab(i,ii,iii,iv,v) + 2ab (i,ii,iii,iv,v). Discovered in 1997, not observed in Almiri since 2003. Meligou spring is transformed in a bathing area, but the species seems to survive in the adjacent lagoon (2004).

Further reading. Kottelat et al., 2007: 15 (description).

Aphanius baeticus

Common name. Guadalquivir toothcarp.

Diagnosis. Distinguished from other species of *Aphanius*, Valenciidae and Fundulidae in Europe by: ● male with dark grey caudal, with a distinct submarginal bar and 4–5 vertical rows of hyaline dots sometimes organised into regular bars / ○ male with 14–17 dark grey bars on a silvery background, bars irregularly shaped and set, often connected / ● female with a few large black spots on side, usually organised into two rows,

Aphanius almiriensis

Aphanius baeticus

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Aphanius baeticus; Cabezas de San Juan, Spain; male. R. Wildekamp

Aphanius fasciatus; Skanes, Tunisia; male. R. Wildekamp

one on middle of flank, one level with pectoral base / ♂ 24–26 scales in lateral line series on body / ♂ 9–10 pectoral rays / ♂ usually 9½ anal rays. Size up to at least 30 mm SL.

Distribution. Spain: along Atlantic coast between Huelva and Gulf of Cadiz, known from 9 localities (extirpated in one of them).

Habitat. Lagoons, tidal canals and small, shallow coastal streams, with water fresh to hypersaline, with silt bottom.

Biology. Lives about 1 year, exceptionally 2 years. Spawns a few eggs daily in April – September. Individuals born in spring mature at 3–4 months and spawn the same year; those born later spawn the following year. Omnivorous; feeds on zooplankton, small insects, vegetal matter and detritus.

Conservation status. EN A2ce. Freshwater populations strongly impacted by introduced *Gambusia holbrooki* and *Fundulus heteroclitus*. Hypersaline populations apparently not affected, but very isolated.

Further reading. Fernández-Delgado et al., 1988 (reproduction; as *A. iberus*); Doadrio et al., 2002: 74 (description).

Aphanius fasciatus

Common name. Mediterranean toothcarp.

Diagnosis. Distinguished from other species of *Aphanius*, Valenciidae and Fundulidae in Europe by: ♂ male with pale yellow to yellow-orange caudal, in some populations with a wide dark submarginal bar / ♂ male with 8–15 dark blue to grey bars on a silvery background, bars usually regularly shaped and set / ● female with 11–17 short dark brown bars on sides, over a faint greyish midlateral stripe / ♂ 24–29 scales in midlateral series on body / ♂ 14–15 pectoral rays. Size up to about 60 mm SL.

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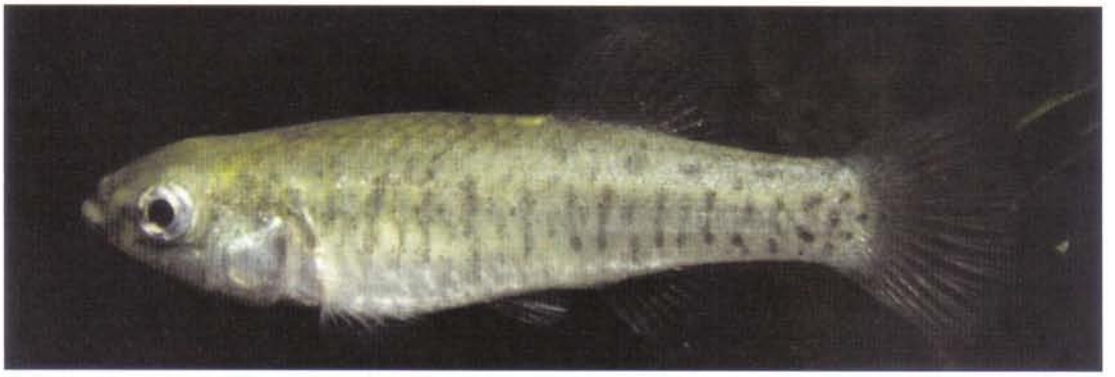
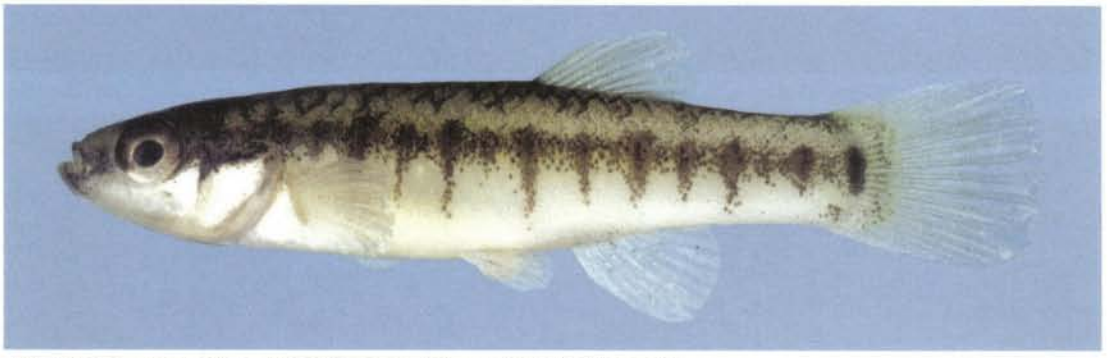


Aphanius fasciatus; Modica, Sicilia, Italy; female. R. Wildekamp



Aphanius fasciatus; Messolonghi Lagoon, Greece; female, 27 mm SL.

Distribution. Mediterranean shores, from Camargue (France) and western Algeria eastward, including Corsica, Sardinia, Sicily, Malta, Crete and Cyprus; inland water bodies from Algeria to Egypt. In Spain, recently appeared in Ebro delta, suspected to have been released by aquarists. Entered Bitter Lakes in Egypt through Suez canal.
Habitat. Coastal lagoons, in hypersaline to shallow still to slow-flowing fresh water, especially at river mouths.
Biology. Spawns for the first time at 7–12 months. Spawns in March – June in Italy, April – July in Greece, April – September in Corsica. Spawns on bottom and in submerged vegetation. Eggs hatch in 10–14 days. Juveniles form large schools. Feeds on small benthic or planktonic invertebrates and algae.
Conservation status. LC. Suffers from competition with introduced species, especially *Gambusia holbrooki*.
Further reading. Tigano & Ferrito, 1985 (osteology); Gandolfi et al., 1991: 361 (biology); Wildekamp, 1993: 48 (description); Leonardos & Sinis, 1998: 171 (reproduction); Kottelat et al., 2007: 23 (systematics).

Aphanius iberus

Common names. Fartet, Spanish toothcarp.
Diagnosis. Distinguished from other species of *Aphanius*, Valenciidae and Fundulidae in Europe by: ● male with caudal hyaline to bluish-grey, with 2–5 dark grey bars / ○ male with 10–20 dark grey to dark blue bars on a silvery background, bars usually irregularly shaped and set, often con-

Aphanius fasciatus

Aphanius iberus

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Aphanius iberus; Estartit, Spain; male, without pelvics. R. Wildekamp

Aphanius iberus; Peniscola, Spain; female. R. Wildekamp

nected, breaking up into a mosaic of dark blue and silvery spots along back and in posterior part of body / ● female with numerous dark brown spots on sides and back / O 23–27 scales in lateral line series on body / O 9–10 pectoral rays / O usually 7–8½ anal rays. Size up to about 45 mm SL.

Distribution. Spain: along Mediterranean coast, known from 30 localities (extirpated in 14 of them). Historical records from near Perpignan (France) where it is extirpated.

Habitat. Lagoons, salt marshes, swamps, estuaries and freshwaters. Euryhaline, in salinities ranging from freshwater to 57 ‰.

Biology. Lives about 1 year, exceptionally 2 years. Only a few adults survive spawning period and following winter. Spawns a few eggs every day in May – September. Omnivorous; feeds on zooplankton, small insects, vegetal matter and detritus.

Conservation status. EN A2ce. Mediterranean coast populations are suffering from competition with *Gambusia holbrooki*; as a result, *A. iberus* has disappeared from freshwaters and survives only in the saline or hypersaline zones.

Remarks. A population from formerly endorheic Villena Lagoon (Alicante) is distinguished by a much stouter caudal peduncle (depth 0.6–1.6 times in its length, vs. 1.4–2.4 in other populations) and apparently should be treated as a distinct species; a drainage channel, however, has brought this population in contact with other *A. iberus* population and this resulted in introgression. Populations from the coast of Algeria and the Atlas along the Morocco-Algeria border have long been identified as *A. iberus* but they belong to *A. saourensis* and other, unnamed and possibly extinct, species.

Further reading. Wildekamp, 1993: 54 (description); Vargas & de Sostoa, 1997 (biology); Doadrio, 2001: 232 (biology, conservation); Doadrio et al., 2002 (systematics); Blanco et al., 2006 (phylogeny).

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Family Gasterosteidae

Sticklebacks

A small family with 5 genera and about 15 species from fresh and coastal waters of Eurasia and northern America. They are distinguished by the presence of a series of spines in front of the dorsal fin, a single spine in the anal fin, a pair of pelvic spines (missing in many species), and in most species a number of bony scutes on the flank and on the caudal peduncle. In most species, the male builds a nest made of vegetal debris and algae, in the substrate or anchored to submerged vegetation. The nest is held together by a thread-like substance secreted by the kidney and which act as glue. The male leads the female into the nest where the eggs are laid and fertilized. The nest and later the young are guarded by the male.

The number of species in the family is apparently greatly underestimated. Several populations from northern Eurasia and America had earlier been placed in *Gasterosteus aculeatus*, but this had not been based on proper taxonomic analyses. A re-analysis of the Holarctic populations using explicit taxonomic principles and avoiding generalisations, based on observations of individual populations, suggest that several distinct species should be recognized. The name *G. aculeatus* is now restricted to the freshwater populations of eastern Europe and the coastal populations of northern Europe. The populations from western Europe and the Mediterranean basin are called *G. gymnurus*. There is a narrow fringe in the English Channel, North and Baltic Seas where *G. aculeatus* and *G. gymnurus* came into contact after the Pleistocene glaciations and hybridised. In this hybrid zone, *G. aculeatus* and *G. gymnurus* may co-occur. Usually a bimodal distribution of typical *G. aculeatus*, typical *G. gymnurus* and a few intermediate fish are found in these mixed populations. Few intermediate individuals are often found in pure populations in the hybrid zone, especially along the coasts of Baltic and North Seas. In Europe, pure populations of partly plated sticklebacks are known from Iceland (*G. islandicus*) and from Romania (*G. crenobiontus*). *Gasterosteus* without pelvic spines or pelvic girdle and variable dorsal spine counts are known from lakes in North Uist, Outer Hebrides.

Further reading. McLennan & Mattern, 2001 (phylogeny); Mattern & McLennan, 2004 (phylogeny).

Key to genera of Gasterosteidae in Europe

1a – 7–11 isolated spines in front of dorsal; pelvic spines distinct or absent; or if 2–6 dorsal spines then pelvic spines absent. ..... *Pungitius*

1b – 2–6 isolated spines in front of dorsal; pelvic spines distinct. 2

2a – Usually 4–6 isolated spines in front of dorsal; no bony scutes on flank. ..... *Culaea*

2b – Usually 2–3 isolated spines in front of dorsal; bony scutes usually present on flank, at least above pelvic spine. ..... *Gasterosteus*

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Culaea inconstans; Danube drainage, Germany; male in front of nest, ~60 mm SL. A. Hartl

Culaea inconstans; Danube drainage, Germany; female, ~40 mm SL. A. Hartl

Culaea inconstans

Common name. Brook stickleback.

Diagnosis. Distinguished from other species of Gasterosteidae in Europe by: ○ 4–6 short dorsal spines, never inclined to the left or to the right / ○ no keel on side of caudal peduncle / ○ anal origin slightly behind dorsal origin / ○ body dark olive green (getting blackish in breeding males), with numerous pale spots or undulating bars on flank. Size up to 80 mm SL.

Distribution. Native to Atlantic and Arctic basins in Canada and northern half of U.S.A. Introduced in upper Inn drainage in Bavaria (Germany) and accidentally in the 1960's with *Micropterus* to southern Finland where it has established a population in Lake Lohjanjärvi.

Habitat. Small clear, cold streams, ponds and lakes, with dense aquatic vegetation.

Biology. Stays in aquatic vegetation. Spawns for the first time at 1 year. Territorial during spawning season (April – July in Canada, unstudied in Europe). Males build a nest 2–3.5 cm in diameter on reeds, grass or on bottom. The nest is made of algae and leaves. Males guard the nest from spawning until larvae swim away a few weeks later. Eggs hatch in 8–9 days. Feeds on small aquatic insects and crustaceans.

Conservation status. Alien.

Further reading. Scott & Crossman, 1974: 708 (biology); Nelson & Paetz, 1992: 319 (biology); Koli, 2001 (introduction).

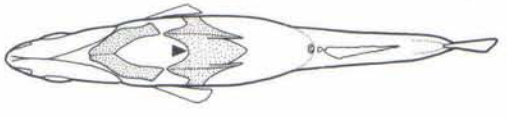

Figure 78 Pelvic girdle of *Gasterosteus islandicus*. Arrow points to notch in pelvic girdle (after Penczak, 1964).

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Key to species of *Gasterosteus* in Europe

1a – Anterior margin of pelvic girdle with a deep notch (Fig. 78). ..... *G. islandicus*

1b – Anterior margin of pelvic girdle straight or rounded. 2

2a – No scutes on caudal peduncle; trunk without or with only 2–10 bony scutes. ..... *G. gymnurus*

2b – Scutes present on caudal peduncle; trunk and caudal peduncle covered by 13–35 bony scutes. 3

3a – Posterior edge of scutes crenulated; scutes above anal base present; trunk and caudal peduncle covered by a complete series of 29–35 scutes. ..... *G. aculeatus*

3b – Posterior edge of scutes smooth; no scutes above anal base; 13–17 scutes on trunk and caudal peduncle. ..... *G. crenobiontus*

Gasterosteus aculeatus

Common name. European threespine stickleback.
Diagnosis. Distinguished from other species of *Gasterosteus* in Europe by: ● trunk and caudal peduncle covered by a complete series of 29–35 bony scutes / ○ posterior edge of scutes crenulated / ○ scutes forming a lateral keel on caudal peduncle. Scutes may be missing on posterior part of trunk in hybrid zone with *G. gymnurus* and in some isolated freshwater populations of northeastern Europe. Size up to about 100 mm SL, usually about 60-70 mm SL.
Distribution. North Sea coasts of Scotland and Scandinavia, coasts of Iceland and White Sea, Atlantic coasts from Ireland northward, southeastern shore of Baltic Sea and its basin (Odra and

Gasterosteus aculeatus; Texel, Netherlands; anadromous male, ~60 mm SL.

Gasterosteus aculeatus; Warta, Odra drainage, Poland; non-anadromous male, ~55 mm SL.

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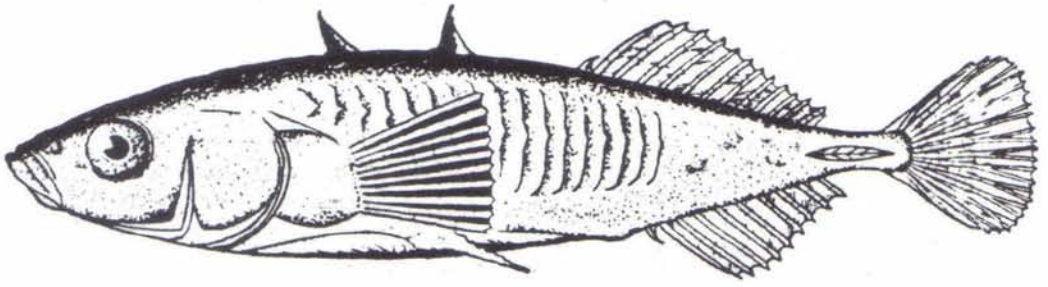


Gasterosteus crenobiontus; Lake Techirghiol, Romania; ~50 mm SL. (from Băcescu & Mayer, 1956)

Vistula drainages), shores of Black Sea and its northern basin (from Danube to Kuban drainages), southern shore of Caspian Sea. Almost absent inland in Finland, except north of 68°N. Absent in upper Danube. Hybrid zone with *G. gymnurus* in English Channel, southern North Sea, Baltic Sea and their basins. Introduced to northern Italy.

Habitat. At sea: shallow coastal areas. In freshwaters, prefers small streams, but may be found in a variety of habitats including lakes and large rivers.

Biology. Anadromous, with numerous non-anadromous populations in brackish or pure freshwater, rarely in marine waters. Usually forages at sea until 2 years old, then moves to lower part of rivers in March – April to reproduce. Freshwater populations usually spawn for the first time at 1 year. Spawns at temperatures above 12°C. In spawning season, males develop a bright orange to red belly and blue-green flank and eyes. They defend territories, in which in April – June they construct a nest on the bottom, in relatively shallow areas, very rarely attached to plants. They dig a depression up to 14 × 10 cm to which they bring plant materials (especially filamentous algae), which are glued together with kidney secretions. Several females are individually led to the nest to spawn, then chased away. Males guard and fan eggs to provide them with oxygenated water. Spawning behaviour is very stereotyped. Eggs hatch in 7–8 days and juveniles are guarded for a few days after which the male abandons the nest. Anadromous individuals usually die of exhaustion after spawning cycle while freshwater individuals are able to complete several cycles within one year or sometimes over several years. Juveniles move to sea (anadromous populations) or to deeper, larger water bodies (freshwater populations) in July – August where they form large feeding schools. Feeds on small aquatic invertebrates, especially insects and crustaceans.

Conservation status. LC.

Remarks. Populations from the Baltic and Black Sea basins have not yet been compared in detail. Molecular data and preliminary morphological observations suggest that they are probably distinct species.

Further reading. Paepke, 1983: 68 (biology); Bell & Foster, 1994 (biology); Kottelat, 1997: 164 (systematics); Mäkinen et al., 2006 (genetics).

Gasterosteus crenobiontus

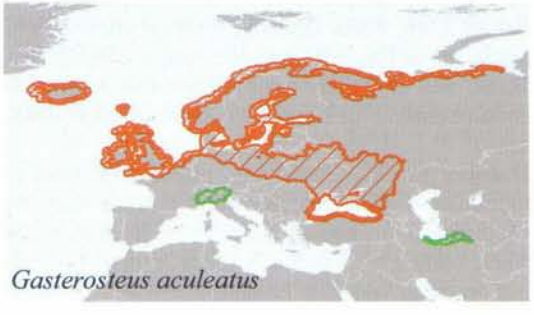
Common name. Techirghiol stickleback.

Diagnosis. Distinguished from other species of *Gasterosteus* in Europe by: ● 13–17 scutes on trunk, no scutes above anal base / ● posterior edge of scutes smooth / ○ scutes forming a lateral keel on caudal peduncle. Size up to 65 mm SL.

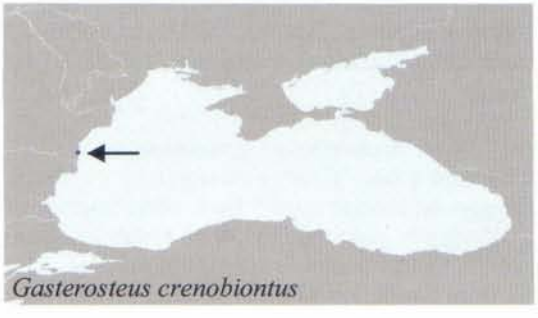
Distribution. Romania: freshwater springs of hypersaline littoral Lake Techirghiol (south of Constanta).

Habitat. Freshwater springs.

Biology. Spawns during an extended period, in February – October.



Gasterosteus aculeatus



Gasterosteus crenobiontus

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Gasterosteus gymnurus; northern Wadden Sea, Denmark; marine form, female, ~60 mm SL. O. Seehausen

Gasterosteus gymnurus; Rhine drainage, Germany; male, ~75 mm SL.

Gasterosteus cf. *gymnurus*; Moraca, Drin drainage, Montenegro; male, ~60 mm SL.

Conservation status. Extinct* as a result of hybridisation with *G. aculeatus*. The springs inhabited by *G. crenobiontus* used to be separated from the habitat of *G. aculeatus* by a hypersaline lake that served as a barrier between the species. Irrigation works transformed the lake into a brackish one, which was invaded by migratory *G. aculeatus*.
Further reading. Băcescu & Mayer, 1956: 24 (morphology, habitat); Bănărescu, 1994b: 8 (extinction).

Gasterosteus gymnurus

Common name. Western threespine stickleback.
Diagnosis. Distinguished from other species of *Gasterosteus* in Europe by: ● no scutes or lateral keel on caudal peduncle (except in few individuals from Sardinia) / ○ trunk without or with only 2–10 bony scutes / ○ scutes overlapping. Scutes may be more numerous and present on caudal peduncle in hybrid zone with *G. aculeatus*. Size up to about 100 mm SL, usually about 60-80 mm SL.
Distribution. Mediterranean basin (including Mallorca, Sardinia, Corsica), Atlantic basin south of English Channel and along western slope of British Isles; Rhine drainage. Hybrid zone with *G. aculeatus* in English Channel, southern North Sea, Baltic Sea and their basins. Introduced to Switzerland (native in Basel). Invasive in upper Danube.
Habitat. Streams, lakes and ponds with slow to moderate current, clear water, sand bottom. In Mediterranean basin, commonly in spring-fed water bodies, also found in other habitats (including brackish water in Po delta).

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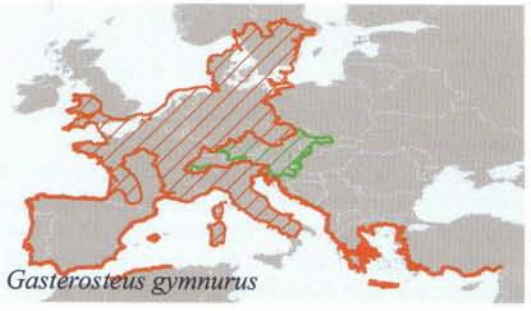
Gasterosteus sp.; Danube drainage, Germany; **a-d,** male preparing the nest; **e,** male leading female into the nest; **f,** male cleaning eggs in nest. A. Hartl

Biology. Freshwater, non-migratory species. Reproduces in April – May in Spain, in Italy in May – July in springs and earlier in brackish waters. Spawns at temperatures above 12°C. Spawns for the first time at 1 year. In spawning season, males develop a vivid red belly. They defend territories, in which they construct a nest on the bottom, in relatively shallow areas. They dig a depression to which they bring plant materials, which are glued together with kidney secretions and covered by sand, leaving only the entrance distinct. Several females are then led in turn to the nest to spawn, then chased away. Males guard and fan eggs to provide them with oxygenated water. Spawning behaviour very stereotyped. Eggs hatch in about 10 days and juveniles are guarded for a few days, after which the male abandons the nest. Feeds mainly on small invertebrates.

Conservation status. LC. Locally rare or extirpated in several Mediterranean drainages.

Remarks. The name *G. leiurus* is often and erroneously used for this species. Molecular data and



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Gasterosteus islandicus; Lake Leirvogsvatn, Iceland; ~30 mm SL. G. Fridriksson

preliminary morphological observations suggest that several of the isolated populations in the Mediterranean basin should possibly be recognized as distinct species.

Further reading. Bianco & Taraborelli, 1988 (morphology of Sardinian populations); Gandolfi et al., 1991: 381 (biology); Kottelat, 1997: 165 (systematics, nomenclature); Mäkinen et al., 2006 (genetics).

Gasterosteus islandicus

Common name. Iceland stickleback.

Diagnosis. Distinguished from other species of *Gasterosteus* in Europe by: ● anterior margin of pelvic girdle with a deep notch (Fig. 78) / ○ 2–15 scutes on trunk / ○ scutes forming a lateral keel on caudal peduncle or keel absent. Size up to 55 mm SL.

Distribution. Iceland; some populations with low scute number in Norway and northern Finland possibly belong to this species.

Habitat. Streams and lakes.

Biology. No information. Most likely similar to *G. aculeatus*. Morphological differences are reported in several lakes between individuals inhabiting different substrates (mud, lava), especially in Lake Thingvalla.

Conservation status. LC.

Further reading. Penczak, 1964: 442 (morphology); Kottelat, 1997: 165 (systematics); Kristjansson et al., 2002 (morphology).

Key to species of *Pungitius* in Europe

1a – Pelvic girdle absent or very reduced; 2–6 dorsal spines; no keel on side of caudal peduncle. ..... *P. hellenicus*

1b – Pelvic girdle complete; 8–11 dorsal spines; keel on side of caudal peduncle present or absent. 2

2a – Large lateral scutes present on flank. ..... *P. platygaster*

2b – No lateral scutes on flank. 3

3a – Scutes present on caudal peduncle, forming a keel. ..... *P. pungitius*

3b – No scutes on caudal peduncle. ..... *P. laevis*

Pungitius hellenicus

Common name. Greek stickleback.

Diagnosis. Distinguished from other species of *Pungitius* in Europe by: ● 2–6 dorsal spines / ● pelvic girdle absent or very reduced / ○ no keel on side of caudal peduncle / ○ body pale olive, with blackish mottling. Size up to about 45 mm SL.

Distribution. Greece: a few ponds and springs in lower Sperchios drainage.

Habitat. Spring-fed streams and ponds, with temperature rarely rising above 20°C and dense vegetation.

Biology. Spawns in May – June. Maximum recorded age 18 months. Males build a nest made of

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Pungitius hellenicus; Sperchios drainage, Greece; 27 mm SL.

Pungitius laevis; Somme drainage, France; 45 mm SL.

vegetal material, where females lay the eggs. Eggs are guarded by the male until hatching. Feeds on small aquatic invertebrates and fish larvae.
Conservation status. CR B2ab(i,ii,iii,iv,v). Threatened by habitat alteration and water abstraction.
Further reading. Keivany et al., 1997 (systematics), 1999: 390 (conservation); Keivany & Nelson,1998: 430 (osteology), 2000: 558 (morphology).

Pungitius laevis

Common name. Western ninespine stickleback.
Diagnosis. Distinguished from other species of *Pungitius* in Europe by: ○ absence of lateral scutes / ○ no scutes on side of caudal peduncle (keel actually present but not visible externally) / ○ 8–10 dorsal spines / ○ caudal peduncle deeper than wide. Size up to 80 mm SL.
Distribution. Coastal areas of western Europe, from the Netherlands to the Garonne drainage (France), Ireland, southern Great Britain.
Habitat. Shallow still water with dense vegetation.
Biology. Spawns at 1 year in April – June. Males build a nest hanging to aquatic vegetation and take care of eggs and larvae. Eggs hatch in 10–20 days. Dies at end of spawning season. Feeds mainly on zooplankton, small crustaceans and benthic insects.
Conservation status. LC.
Remarks. Very similar to and earlier considered as a subspecies of *P. pungitius*. There is a narrow fringe in northern France and Netherlands where some naked individual occur among populations

Gasterosteus islandicus

Pungitius hellenicus

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Pungitius platygaster; Danube delta, Romania; ~45 mm SL.

usually with a low number of lateral plates; this is considered as an area where the two species came into contact after the Pleistocene glaciations and have hybridised.

Further reading. Kottelat, 1997: 166 (systematics); Keivany & Nelson, 2000: 118 (systematics).

Pungitius platygaster

Common name. Ukrainian stickleback.

Diagnosis. Distinguished from other species of *Pungitius* in Europe by: ● presence of large lateral scutes / ○ no keel on side of caudal peduncle / ○ 8–11 dorsal spines. Size up to 60 mm SL.

Distribution. Lower course of rivers draining to northern shore of Black, Caspian and Aral Sea basins, Danube drainage as far upstream as Belgrade; isolated populations in Axios and Aliakmon drainages (Greece). Also in upper Tobol system (Ob drainage), Lake Issyk-kul basin (Kyrgyzstan) and Sarysu drainage (central Kazakhstan).

Habitat. Swamps and slow-flowing streams with dense vegetation; occasionally enters brackish water.

Biology. Spawns for the first time at 1 year. Feeds on benthic invertebrates. Spawns in spring when temperature reaches 15°C. Territorial during spawning season. Males build a nest made of filamentous algae and submerged plants, with a separate entrance and exit. Males guard the nest until the young swim away a few weeks later. Females lay about 90 eggs.

Conservation status. LC.

Remarks. *P. aralensis*, from the Aral Sea basin, earlier considered as a subspecies of *P. platygaster*, is a distinct species.

Further reading. Keivany & Nelson, 2000: 118 (systematics); Paepke, in Bănărescu & Paepke, 2002: 267 (biology).

Pungitius pungitius

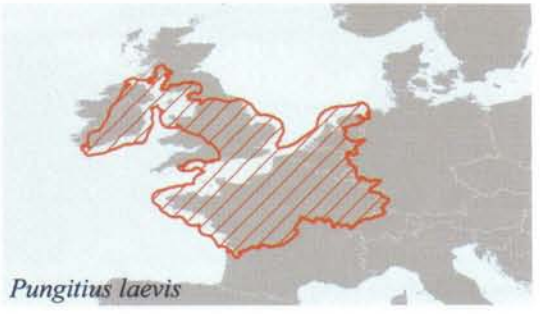
Common name. Eurasian ninespine stickleback.

Diagnosis. Distinguished from other species of *Pungitius* in Europe by: ● scutes on side of caudal peduncle, forming a keel / ○ no scutes on flank / ○ 7–11 dorsal spines / ○ caudal peduncle wider than deep. Size up to 64 mm SL.

Distribution. Coastal areas of northern Europe, from Netherlands to northern Russia, including southern Norway and Baltic basin. Widespread inland in eastern Scandinavia. Extends eastward to Siberia and Japan, but it remains to be demonstrated that East Asian populations are conspecific with European ones.

Habitat. Small freshwater streams and ponds, with dense aquatic vegetation. Enters brackish water along shores of Baltic and Barents Seas, rarely along North Sea shore.

Biology. Individuals born in early spring may mature in 3 months and spawn the same year. Territorial during spawning season, in March – September in central Europe, June – July in Arctic areas. Males build a tube-shaped nest anchored on aquatic vegetation or to the bottom, with a separate entrance and exit. The nest is made of pieces of plants or filamentous algae. Males guard the nest from spawning until larvae swim away a few



Pungitius laevis

Pungitius platygaster

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Pungitius pungitius; Elbe drainage, Germany; ~50 mm SL.

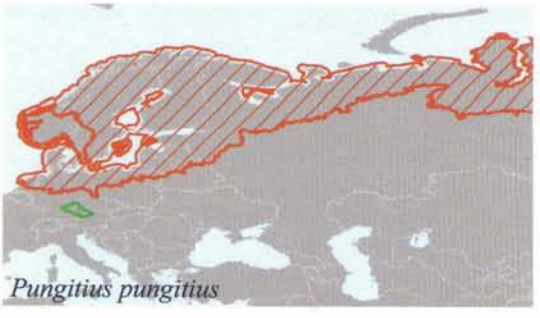
Pungitius pungitius; lower Weser, Germany; ~40 mm SL.

Pungitius pungitius; Elbe, Germany; ~40 mm SL. A. Hartl

weeks later. Eggs hatch in 6–7 days. Feeds predominantly on aquatic invertebrates.

Conservation status. LC.

Further reading. Paepke, 1983: 31 (biology); Keivany & Nelson, 2000: 117 (systematics).



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Family Syngnathidae

Pipefishes

Syngnathidae are characterised by an elongate body covered by a series of bony rings, a small mouth at the extremity of a long and slender snout, and the absence of pelvic fins (and also caudal, dorsal and/or anal fins in some species). The best known members of the family are probably the marine sea horses (genus *Hippocampus*). The family includes some 220 species, most of them in tropical marine waters. Several species enter estuaries and coastal lagoons and some are strictly freshwater inhabitants. A single species (*Syngnathus abaster*) enters freshwater habitats in Europe and is included here. Five additional species are occasionally recorded to enter brackish waters of estuaries and coastal lagoons and might accidentally find their way into freshwater. These species can be distinguished using the key below.

A pipefish's body consists of a series of rings around longitudinal ridges. *Trunk rings* begin with the ring bearing the pectoral base and end with the ring bearing the anus (which usually bears the anal fin). *Predorsal rings* end with the ring bearing the first dorsal ray. *Caudal rings* begin with the first ring behind the anus and end with the penultimate ring (the terminal ring bears the caudal fin).

Further reading. Dawson, 1985; Kuiter, 2000.

Key to species of Syngnathidae in European fresh and brackish waters

1a – Caudal, pectoral and anal absent (Atlantic, Mediterranean and Black Sea). ..... *Nerophis ophidion*

1b – Caudal, pectoral and anal present. 2

2a – Anterior trunk rings not fused ventrally; snout compressed, anterior part deeper than head; up to 350 mm SL (Atlantic, Mediterranean and Black Sea). ..... *Syngnathus typhle*

2b – Anterior trunk rings ventrally fused; snout cylindrical. 3

3a – An elongated bump on top of head behind eye (Atlantic, Mediterranean and Black Sea). ..... *Syngnathus acus*

3b – No elongated bump on top of head behind eye, dorsal profile of head almost linear. 4

4a – Caudal somewhat angulous, diamond-shaped (Atlantic). ..... *Syngnathus rostellatus*

4b – Caudal rounded. 5

5a – Snout depth 6–8 times in its length; snout length more than half of head length (Adriatic). ..... *Syngnathus taenionotus*

5b – Snout depth 2–4 times in its length; snout length half or less than half of head length (Mediterranean and Black Sea, Atlantic south of Bay of Biscay). ..... *Syngnathus abaster*

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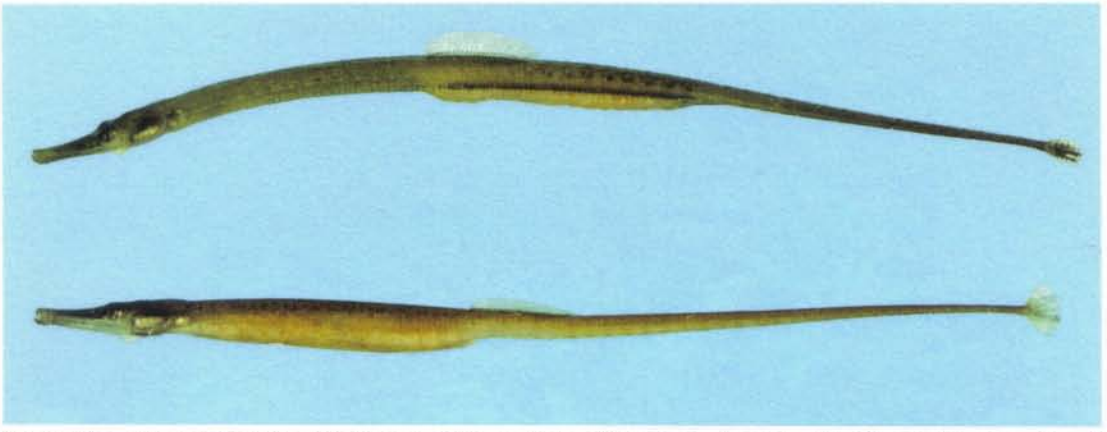


Syngnathus abaster; Messolonghi Lagoon, Greece; male with egg pouch under tail, 92 mm SL (above); and female, 85 mm SL (below).

Syngnathus abaster; Danube delta, Romania; ~90 mm SL.

Syngnathus abaster

Common name. Shore pipefish.

Diagnosis. Distinguished from other species of Syngnathidae entering freshwaters in Europe by: O caudal, pectoral and anal present / O snout cylindrical, length half or less than half of head length, depth 2–4 times in length / O predorsal length 40–42 % SL / O 14–15 predorsal rings / O caudal rounded / O no elongated bump on top of head behind eye. Size up to 190 mm SL.

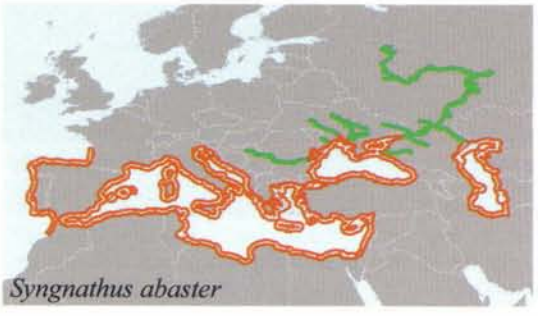
Distribution. Coastal habitats and lower reaches of rivers in Caspian, Black and Mediterranean Sea basins; Atlantic coast from Gibraltar to southern Bay of Biscay; in Danube reaching Romanian-Hungarian border; in Dniepr reaching Kiev. Introduced in reservoirs of middle and lower Volga with mysids brought from Don estuary, now spreading and already south of Moscow.

Habitat. A wide range of marine, brackish- and fresh-water habitats, mostly associated with dense submerged vegetation but as well found on open mud bottom.

Biology. Lives up to 4 years. Spawns for the first time at 1 year. Spawns in April – October. Females lay 10-60 eggs into a brood pouch on ventral surface of tail of males. Males fertilise the eggs as they enter the pouch. Eggs incubate in the male's brood pouch for about 20–32 days, depending of temperature. Feeds on small invertebrates.

Conservation status. LC.

Further reading. Svetovidov, 1964: 183 (description, as *S. nigrolineatus*); Silva et al., 2006a-b (reproduction).



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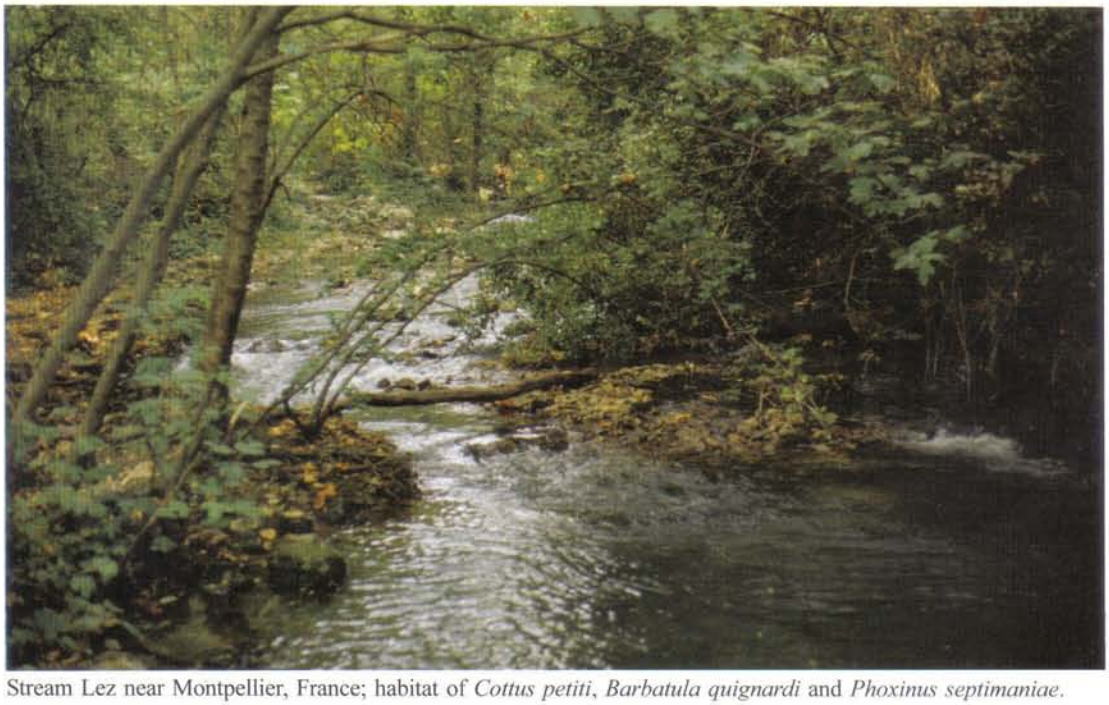
Cottus gobio; upper Danube drainage, Germany; ~100 mm SL. A. Hartl



Stream Lez near Montpellier, France; habitat of *Cottus petiti*, *Barbatula quignardi* and *Phoxinus septimaniae*.

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Family Cottidae

Sculpins, bullheads

A large family comprising predominantly marine members. Species in European freshwaters are distinguished from superficially similar species of families Gobiidae, Odontobutidae, Percidae and Serranidae by the absence of true scales on body and two separate (non-fused) pelvic fins. Sculpins have a depressed body and live on the bottom, usually hidden under stones. Two genera occur in European waters, *Triglopsis* with a single species with marine, estuarine and freshwater populations; and *Cottus*, which inhabits a variety of cold water habitats from brackish coastal waters in northern Baltic to high altitude headwaters. Several specialised benthic and pelagic lineages inhabit the Lake Baikal basin (Siberia) and have long been considered as distinct families (Comephoridae, Cottocomephoridae, Abyssocottidae), but they are more correctly considered as lineages within Cottidae.

Several species have been confused under the name *Cottus gobio*. We distinguish 15 species of *Cottus* in European waters, based on morphological and molecular data.

Most species are stenotopic inhabitants of cold streams and they tend to be very isolated in their particular habitat as ecological factors do not allow them to migrate across main rivers. Many peri-Mediterranean species have their range restricted to one or a few springs or small water bodies. Populations in small streams located only a few kilometres apart and draining to the same small river (where *Cottus* are absent) often seem to be completely isolated.

All species lay adhesive eggs in a compact clutch on the ceiling of small cavities in gravel or rock bottom. Males guard the eggs until hatching; they may guard the egg clutches of several females. Males do not feed while broodcaring, during which they may loose up to 20 % of body weight. They are generally nocturnal and feed on a wide variety of benthic invertebrates.

An important diagnostic character for several *Cottus* species is the presence, absence and extent of prickles on the body. Prickles are remnants of reduced scales, more or less deeply embedded in the skin. Some species may loose the prickling with growth. The prickling is well developed in juveniles and immature individuals (Fig. 79). Males especially may have reduced prickling when mature. For example, all juveniles of *C. perifretum* have the body entirely prickled up to the caudal peduncle while in mature males the prickling is usually greatly reduced or absent. The degree of prickling given in the key and diagnoses is the one for juveniles. In the hybrid zones between the prickled C. *koshewnikowi* or *C. perifretum* and the almost unprickled *C. gobio* or *C. rhenanus*, respectively, all age classes show a mixed or intermediate prickling. *C. microstomus* shows a great variability of prickling patterns within and between populations.

Further reading. Koli, 1969 (Scandinavian hybrid zone); Witkowski, 1995 (Polish hybrid zone); Englbrecht et al., 2000 (phylogeography); Sideleva, 2003 (Baikal species); Kontula et al., 2003 (Baikal lineages); Šlechtová et al., 2004 (genetics); Freyhof et al., 2005a (systematics).

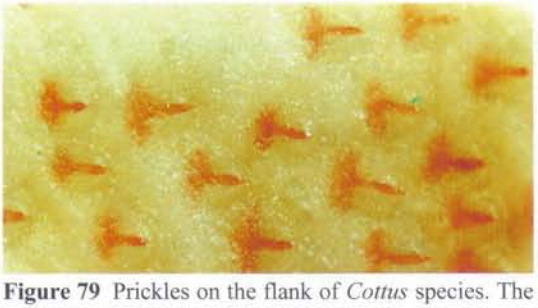

Figure 79 Prickles on the flank of *Cottus* species. The red colour is due to staining with alizarin (a red dye). A. Nolte

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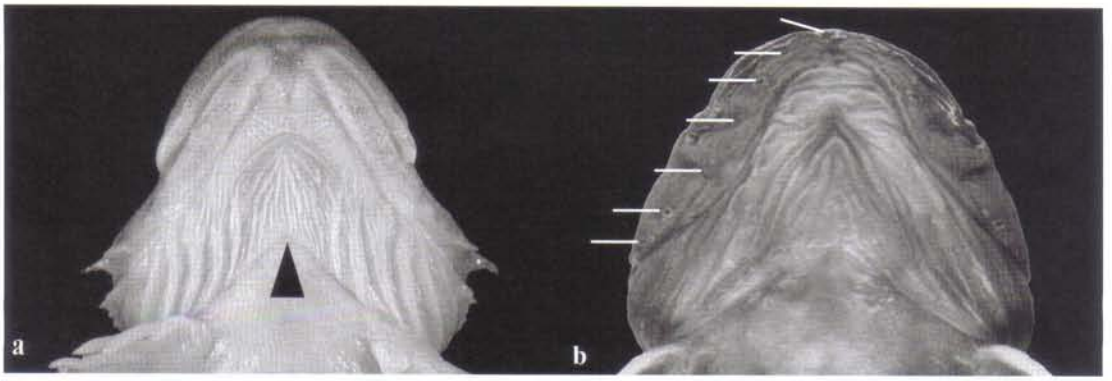

Figure 80 Throat and branchisotegal membranes of Cottidae. **a,** *Triglopsis*; **b,** *Cottus*. Arrow points to membrane continuous across isthmus. White lines indicate position of pores (photograph **a** by B. Delling).

Key to genera of Cottidae in European freshwaters

Lengths are measured from tip of snout, not from tip of upper lip. *Saddles* are dark marks along the dorsal midline, extending downward for some distance on the flank and leaving more or less contrasted pale areas between them along the back.

1a – Four spongy tubercles on head (missing in some populations); upper opercular spine straight, needle-like; caudal peduncle long and slender; rays of second dorsal much longer than rays of first dorsal, produced beyond fin membrane; dorsals clearly separate; pores on lower jaw covered by a membrane; branchiostegal membranes continuous across isthmus (Fig. 80a).
..... *Triglopsis*

1b – No spongy tubercles on head; upper opercular spine hooked, robust; caudal peduncle short and stout; rays of second dorsal not much longer than rays of first dorsal, not produced beyond fin membrane; dorsal not or only slightly separate; pores on lower jaw open and conspicuous (Fig. 80b); branchiostegal membranes attached to isthmus (Fig. 80b), usually not continuous, except in some large males.
..... *Cottus*

Key to species of *Cottus* in Europe

West of the Meuse

1a – Posterior tip of second dorsal reaching rudimentary caudal rays; 28–33 + 1 lateral line pores; 10–12½ anal rays; 14–16½ rays in second dorsal.
..... 2

1b – Posterior tip of second dorsal not reaching rudimentary caudal rays; 31–36 + 1 lateral line pores; 11½–14 anal rays; 15–17½ rays in second dorsal.
..... 3

2a – Body naked; eye diameter 6–8 % SL, 21–27 % HL; dense marbled pattern over poorly contrasted saddles.
..... *C. rondeleti*

2b – Body densely prickled at all sizes; eye diameter 8–10 % SL, 27–31 % HL; very contrasted saddles on an overall greyish body.
..... *C. petiti*

3a – Body covered with prickles, at least in anterior ⅔ and in individuals less than about 50 mm SL.
..... *C. perifretum*

3b – If prickles present, restricted to under pectoral.
..... 4

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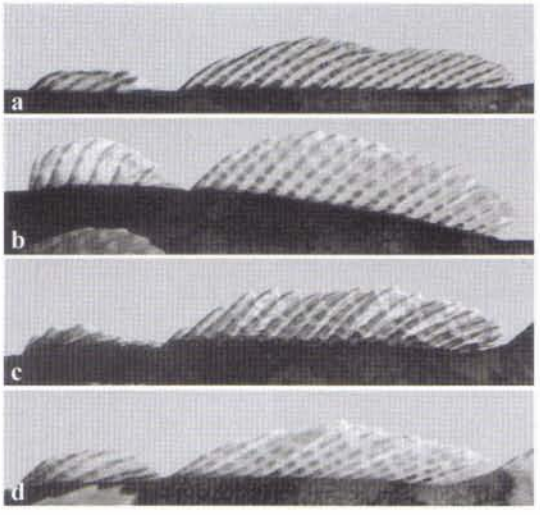

Figure 81 Dorsal fins in *Cottus* species: separate (**a**), reaching (**b, d**) and slightly joined (**c**); first dorsal regularly slanted (**a**), rounded (**b, d**) and truncate anteriorly (**c**); last ray of second dorsal connected (**a, c, d**) and not connected (**b**) to body by a membrane. Body without (**a-c**) and with prickles (**d**).

4a – Two dorsals usually separated in both sexes, more so in males (Fig. 81a); first dorsal low, regularly slanted (Fig. 81a).
..... *C. duranii*

4b – First dorsal reaching second dorsal (Fig. 81b), or slightly joined (Fig. 81c), or only slightly separated; first dorsal rounded or truncate anteriorly.
..... 5

5a – Pelvic rays with conspicuous series of dark brown spots; 33–35 + 1 lateral line pores.
..... *C. hispaniolensis*

5b – Pelvic rays plain yellowish white, or with faint dusky marks; 31–33 + 1 lateral line pores
..... 6

6a – First dorsal low and truncate anteriorly (Fig. 81c); body dark brown, usually with narrow pale vermiculations in lower half, saddles indistinct or poorly contrasted; last anal ray not connected to body by a membrane.
..... *C. aturi*

6b – First dorsal high, regularly rounded (Fig. 81b,d); saddles usually contrasted, body marbled, but not vermiculated; last anal ray connected to body by a membrane on about half of its length.
..... *C. gobio*

From Meuse to Urals

1a – 5–15 distinct rows of spots on pelvic rays; 2 chin pores; prickles, if present, spatulate.
..... *C. poecilopus*

1b – Pelvic plain or with irregular spots; 1 (rarely 2) chin pores; prickles, if present, with triangular base.
..... 2

2a – Lateral line incomplete, reaching to anal base, usually with 17–25 pores; at vertical of 10th ray of second dorsal, lateral line clearly above horizontal midline, distance from dorsal midline to lateral line 1.5–2.1 times in distance from ventral midline to lateral line; prickling on body usually extending backward to caudal peduncle in juveniles.
..... *C. koshewnikowi*

2b – Lateral line complete, reaching to caudal base, usually with 29–37 pores; at vertical of 10th ray of second dorsal, lateral line slightly above horizontal midline, distance from dorsal midline to lateral line 1.0–1.4 times in distance from ventral midline to lateral line; prickling on body variable.
..... 3

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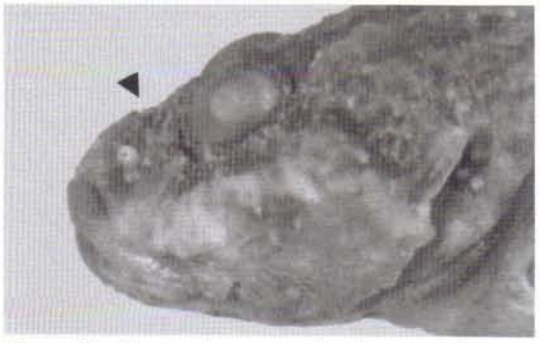

Figure 82 *Cottus microstomus* showing notch in snout between anterior and posterior nares.

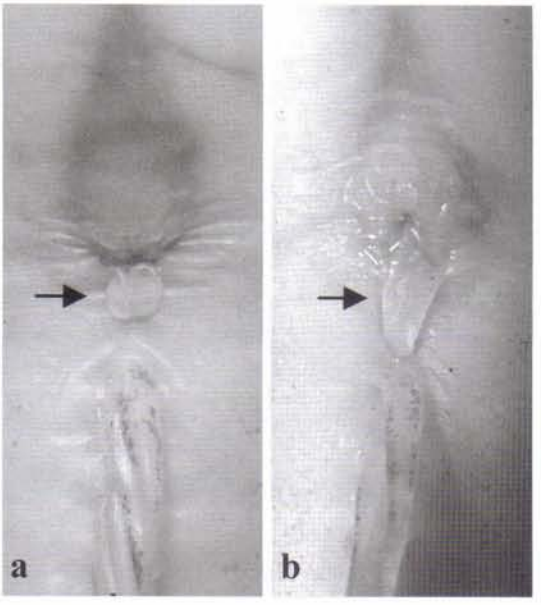

Figure 83 Genital papilla lobular (**a**) and triangular (**b**) in adult males of *Cottus* species.

3a – A shallow transverse groove on snout between anterior and posterior nares (Fig. 82); genital papilla lobular in adult males (Fig. 83a).
..... *C. microstomus*

3b – No transverse groove in snout between anterior and posterior nares; genital papilla triangular or filiform in adult males (Fig. 83b).
..... 4

4a – Prickling on body extending backward to middle of base of second dorsal in juveniles.
..... *C. perifretum*

4b – Prickling on body absent or restricted to under pectoral in juveniles.
..... 5

5a – Body plain reddish brown or with markings slightly darker than background; fins whitish or rays with poorly contrasted rows of spots; first dorsal dark brown to black in live nuptial males; size up to 60 mm SL.
..... *C. scaturigo*

5b – Body with clearly distinct markings; fin rays with several rows of dark spots; first dorsal marbled in live nuptial males; size up to 120 mm.
..... 6

6a – Dorsal head length 19–20 % SL; distance from tip of snout to origin of second dorsal 47–49 % SL.
..... 7

6b – Dorsal head length 20–25 % SL; distance from tip of snout to origin of second dorsal 49–59 % SL.
..... 8

7a – Lateral head length 27–33 % SL; 14–15 (rarely 13) anal rays.
..... *C. haemusi*

7b – Lateral head length 24–27 % SL; 12–13½ anal rays.
..... *C. transsilvaniae*

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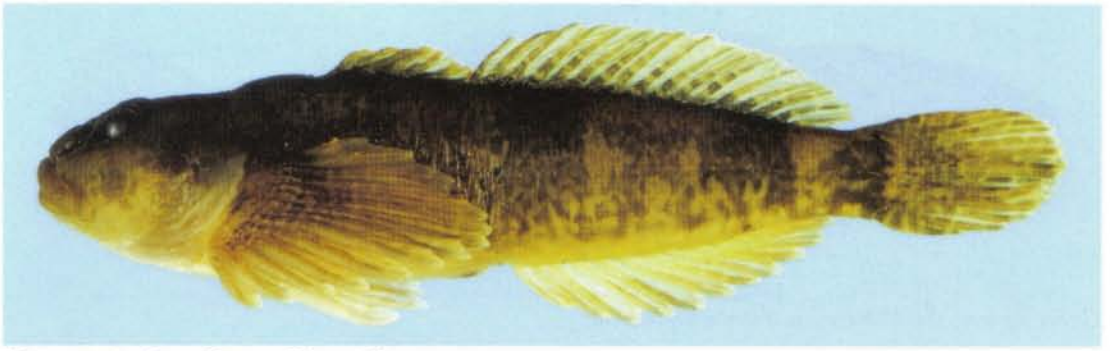

Cottus aturi; Adour, France; 90 mm SL.

8a – Prickling on body present, restricted to under pectoral; predorsal length 35–40 % SL; distance from tip of snout to origin of second dorsal 53–59 % SL. ..... *C. metae*

8b – Prickling on body absent or restricted to less than 10 prickles under pectoral; predorsal length 30–35 % SL; distance from tip of snout to origin of second dorsal 49–55 % SL. 9

9a – First dorsal low, with straight or slightly rounded distal edge in adult males larger than 70 mm SL. ..... *C. rhenanus*

9b – First dorsal elevated, with rounded edge in adult males larger than 70 mm SL. ..... *C. gobio*

Cottus aturi

Common name. Adour sculpin.

Diagnosis. Distinguished from other species of *Cottus* in western Europe by: ○ body large, massive, broad / ○ no transverse bands on pelvic / ○ lateral line complete, usually with 31–32 + 1 pores / ○ no prickling on body / ○ body dark brown, marbled or with narrow vermiculations / ○ first dorsal low and anteriorly truncate (Fig. 81c) / ○ last anal ray not connected to body by a membrane / ○ depth of caudal peduncle 1.5–2.1 times in its length. Size up to 100 mm SL.

Distribution. Adour and Nivelle drainages (France, Spain).

Habitat. Streams with clear, cool, moderate to swift water, and stone substrate.

Biology. No data.

Conservation status. LC.

Further reading. Englbrecht et al., 2000 (genetics); Freyhof et al., 2005a: 132 (description).

Cottus aturi; Adour, France; 90 mm SL.

Cottus duranii

Common name. Dordogne Sculpin.

Diagnosis. Distinguished from other species of *Cottus* in Europe by: ● two dorsals usually separate in both sexes (Fig. 81a) / ○ no transverse bands on pelvic / ○ first dorsal low, regularly

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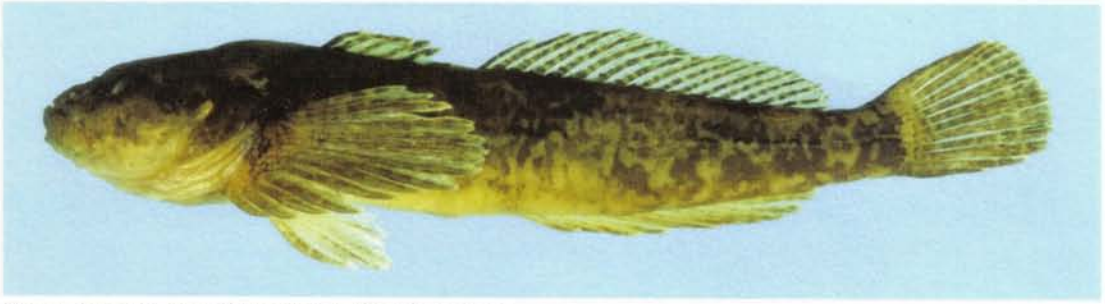
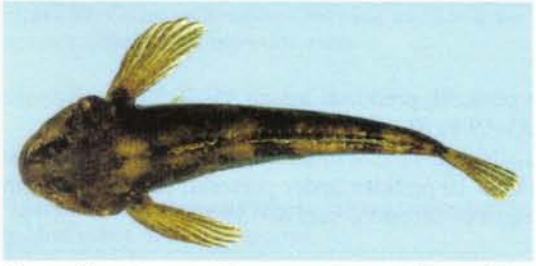
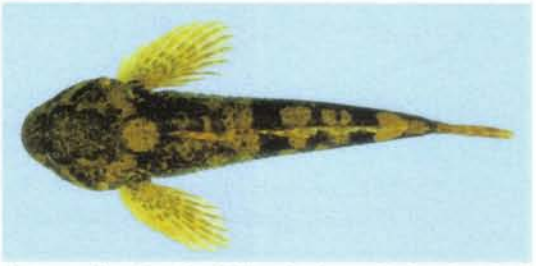


Cottus duranii; upper Dorgogne, France; 95 mm SL.



Cottus duranii; upper Dorgogne, France; 95 mm SL.



Cottus gobio; Doubs, Rhône drainage, Switzerland; 56 mm SL.

Cottus gobio; Elbe drainage, Germany; ~70 mm SL.

slanted (Fig. 81a) / ○ no prickling in adults / ○ first pelvic ray straight and slender. Size up to 100 mm SL.

Distribution. France: upper Dordogne and upper Loire drainages. Populations from upper Lot possibly conspecific.

Habitat. Streams with clear, cool, moderate to swift water, and stone substrate.

Cottus gobio

Biology. No data.

Conservation status. DD.

Further reading. Freyhof et al., 2005a: 136 (description).

Cottus gobio

Common name. Sculpin.

Diagnosis. Distinguished from other species of *Cottus* in Europe by: ○ usually a marked hump between nape and dorsal origin in adults / ○ colour pattern clearly distinct, contrasted / ○ rows of dark brown spots on unpaired fin rays / ○ no transverse bands on pelvic / ○ first dorsal elevated, with rounded distal edge in males larger than 60 mm SL (Fig. 81b), reaching or slightly joined to second dorsal in both sexes (Fig. 81) / ○ first dorsal with black blotch between base of rays 1–3 in both sexes and between rays 6–7 in males / ○ last anal ray connected by a membrane to body along half of its length / ○ prickling absent or only

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Cottus gobio; Scheulte, Rhine drainage, Switzerland; 66 mm SL.

Cottus gobio; Doubs, Rhône drainage, Switzerland; 56 mm SL.

Cottus gobio; Ticino, Po drainage, Switzerland; 73 mm SL.

Cottus gobio; Roya drainage, France; 110 mm SL.

under pectoral / ○ 1 chin pore / ○ lateral line complete, usually with 33–36 + 1 pores / ○ lateral line slightly above horizontal midline; below 10th ray of second dorsal, distance from dorsal base to lateral line 1.0–1.4 times in distance from anal base to lateral line. Size up to 90 mm SL.

Distribution. Northern Baltic basin in Scandinavia south to stream Maurine (53°51'N 10°56'E) in southwesternmost corner of Baltic basin (Germany). Lower reaches of streams and rivers and along coast of Sweden, Finland, Russia southwest to Estonia. Danube (except upper tributaries Save

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Cottus gobio; upper Danube drainage, Germany; ~100 mm SL. A. Hartl

and Arges), Elbe, Ems, Weser and Rhône drainages. Tributaries of upper Rhine downriver (northward) to about Mannheim. A few of the uppermost tributaries of River Tevere, Central Italy. Adriatic drainages, from Potenza (Italy) to Zrmanja (Croatia), except Timavo spring (inhabited by *C. scaturigo*). Locally introduced in Scheldt drainage (Belgium). Sculpins reported from Neretva drainage (Bosnia-Herzegovina) probably also belong to *C. gobio*.

Habitat. Cold, clear and fast-flowing water of small stream to medium-sized rivers. As well on gravel or rocky shores of cold lakes and in slightly brackish waters along eastern Baltic coast.

Biology. Spawns for the first time at 2–4 years. Spawns in March – April, when temperature rises above 12°C. Females spawn once a year. Most individuals spawn for several years. They lay adhesive eggs in a compact clutch on ceiling of small cavities in gravel or rock bottom. Males guard eggs until hatching; a single male may guard the egg clutches of several females. Feeds on a wide variety of benthic invertebrates.

Remarks. Considering its wide range and the

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Cottus hispaniolensis; southern Garonne drainge, France; 91 mm SL.

Cottus hispaniolensis; southern Garonne drainge, France; 91 mm SL.

observed morphological diversity, future studies may show that it comprises several distinct species.
Conservation status. LC, but several populations are seriously threatened.
Further reading. Robins, 1961: 310 (systematics); Koli, 1969 (morphology, Scandinavian populations); Kottelat, 1997: 167 (systematics); Freyhof et al., 2005a: 124 (systematics).

Cottus haemusi

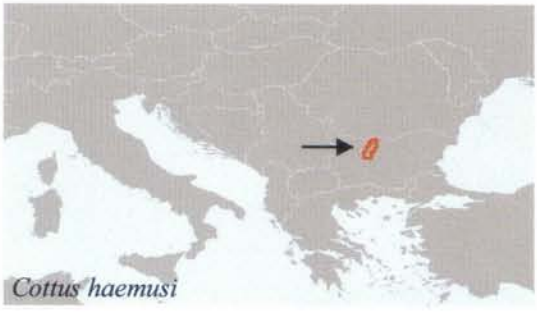
Common name. Vit sculpin.
Diagnosis. Distinguished from other species of *Cottus* in Danube basin by: ○ no transverse bands on pelvic / ○ lateral line complete / ○ no prickling on body / ○ 14–15 (rarely 13) anal rays / ○ usually 17–19 rays in second dorsal / ○ lateral head length 27–33 % SL. Size up to 100 mm SL.
Distribution. Bulgaria: River Beli Vit (Danube drainage), possibly in other lower Danube tributaries.
Habitat. No data. Probably similar to *C. gobio*.
Biology. No data. Probably similar to *C. gobio*.
Conservation status. DD.
Further reading. Marinov & Dikov, 1986 (description).

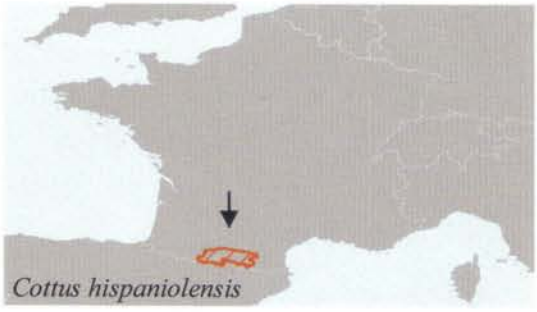
Cottus hispaniolensis

Common name. Pyrrenean sculpin.
Diagnosis. Distinguished from other *Cottus* in western Europe by: ● pelvic with several rows of spots / ○ no prickling in adults / ○ last anal ray with membrane connecting to body along half of its length / ○ last dorsal ray with membrane connecting to body along half to entire length / ○ lateral line complete, with 33–35 + 1 pores. Size up to 105 mm SL.
Distribution. Southern (Pyrrenean) Garonne drainage (France, Spain).
Habitat. Streams with clear, cool, moderate to swift water, and stone substrate.
Biology. No data. Probably similar to *C. gobio*.
Conservation status. LC.
Further reading. Freyhof et al., 2005a: 134 (systematics).

Cottus koshewnikowi

Common name. Volga sculpin.
Diagnosis. Distinguished from other species of *Cottus* in eastern Europe by: ○ no transverse bands on pelvic / ○ 1 chin pore / ○ lateral line incomplete, reaching to anal base, usually with 17–





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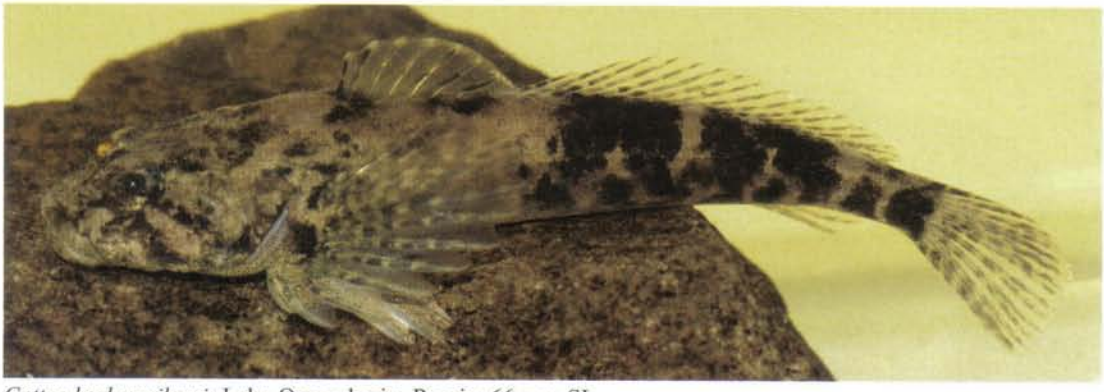

Cottus koshewnikowi; Lake Onega basin, Russia; 66 mm SL.

25 pores / ○ lateral line clearly above horizontal midline; at vertical of 10th ray of second dorsal distance from dorsal midline to lateral line 1.5–2.1 times in distance from ventral midline to lateral line / ○ prickling on body variable, in juveniles usually extending backward to caudal peduncle. Size up to 81 mm SL.

Distribution. Upper Volga drainage and northern and eastern Gulf of Bothnia from Estonia eastward and northward to Finland and northern Sweden. *Cottus* populations from Dniepr, Ural and Pechora drainages tentatively identified as present species.

Habitat. Medium-sized rivers to small streams, lake shores.

Biology. No data. Probably similar to *C. gobio*.

Conservation status. LC.

Remarks. *C. koshewnikowi* and *C. gobio* form a hybrid zone in northern and eastern Gulf of Bothnia. Both species have largely allopatric ranges and where they come into contact, they have different ecologies, with *C. gobio* in partly brackish coastal habitats and *C. koshewnikowi* in pure freshwater inland habitats. *C. milvensis* from River Pechora is included here in *C. koshewnikowi*, but could be a distinct species.

Further reading. Koli, 1969 (hybrid zone in Finland); Freyhof et al., 2005a: 163 (systematics).

Cottus metae

Common name. Barje sculpin.

Diagnosis. Distinguished from other species of *Cottus* in southern, central and eastern Europe by: ○ prickling restricted to under pectoral, very rarely present behind pectoral / ○ lateral line complete, usually with 29–34 pores / ○ usually 12–13½ anal rays / ○ 14–16½ rays in second dorsal / ○ dorsal fins usually slightly separate in female (Fig. 81a) / ○ predorsal length 35–40 % SL / ○ dorsal head length 21–25 % SL / ○ distance from tip of snout to origin of second dorsal 55–59 % SL. Size up to 100 mm SL.

Distribution. Slovenia: upper Save system (Danube drainage).

Habitat. Small streams to medium-sized rivers.

Biology. Spawns for the first time at 2–4 years. Spawns in March – April. Females spawn once a year. Most individuals spawn for several years.

Conservation status. LC.

Further reading. Freyhof et al., 2005a: 156 (description).

Cottus microstomus

Common name. Baltic sculpin.

Diagnosis. Distinguished from other species of *Cottus* in Europe by: ● a transverse groove in snout between anterior and posterior nares (Fig. 82) / ○ prickling on body extending to caudal peduncle (reduced or sometimes absent in some pop-

Cottus koshewnikowi

Cottus metae

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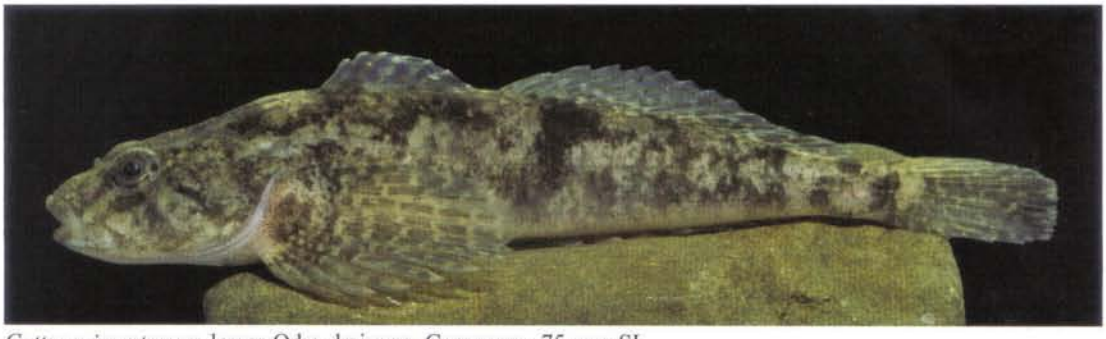
Cottus metae; upper Save, Danube drainage, Slovenia; ~75 mm SL.



Cottus microstomus; lower Odra drainage, Germany; ~75 mm SL.

ulations) / ○ lateral line complete, with 33–36 pores / ○ first dorsal usually reaching second dorsal (Fig. 81b) / ○ genital papilla lobular in males (Fig. 83) / ○ no transverse bands on pelvic. Size up to 100 mm SL.

Distribution. Black Sea basin: Dniestr. Southern Baltic basin in Poland, most likely further east to Lithuania.

Habitat. Small streams to medium sized rivers.

Biology. Spawns for the first time at 2–4 years. Spawns in March – April. Females spawn once a year. They lay adhesive eggs in a compact clutch on the ceiling of small cavities in gravel or rock bottom. Males guard eggs until hatching; a single male may guard egg clutches of several females. Feeds on a wide variety of benthic invertebrates.

Conservation status. LC.

Remarks. *C. microstomus*, *C. gobio* and *C. koshewnikowi* possibly form a hybrid zone in the eastern Baltic basin. Earlier hypothesised hybrid zones in Odra and Vistula drainages seem to be pure *C. microstomus*.

Further reading. Freyhof et al., 2005a: 160 (description).

Cottus perifretum

Common name. Bullhead.

Diagnosis. Distinguished from other species of *Cottus* in western Europe and North Sea basin by: ○ prickling on body extending backward to caudal peduncle in juveniles and most adults, sometimes absent in large males / ○ a distinct predorsal hump in adults / ○ lateral line incomplete in most individuals less than about 60 mm SL (complete in populations from Great Britain and Rhine) / ○ no distinct transverse bands on pelvic / ○ first dorsal fin marbled or black in nuptial

Cottus microstomus

Cottus perifretum

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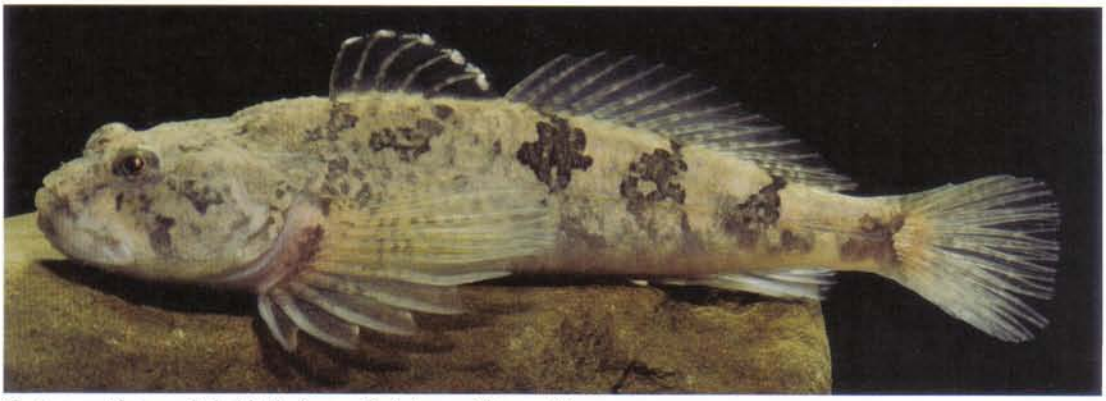
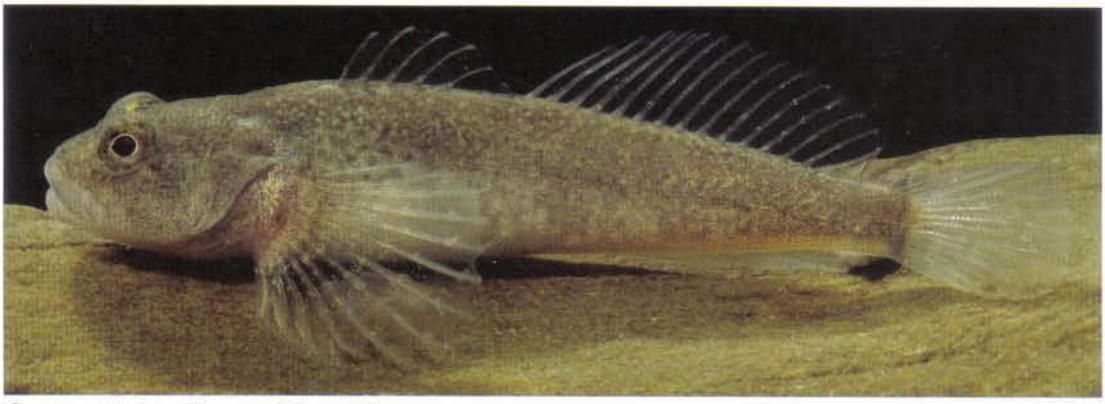


Cottus perifretum; Scheldt drainage, Belgium; ~65 mm SL.



Cottus petiti; Lez, France; ~35 mm SL.

males / ♀ 15½–17½ rays in second dorsal fin / ♀ 11½–14½ rays in anal fin. Size up to 83 mm SL.

Distribution. Great Britain; Atlantic drainages from Garonne (tributaries draining from Massif Central) to Scheldt [French: Escaut] in France and Belgium. Invasive in Rhine drainage in Germany and the Netherlands, reaching upriver (southward) to Karlsruhe. Also in rivers Mosel and Sieg in Germany. Might also be present in other major Rhine tributaries, the French stretch of the upper Rhine and the lower Meuse.

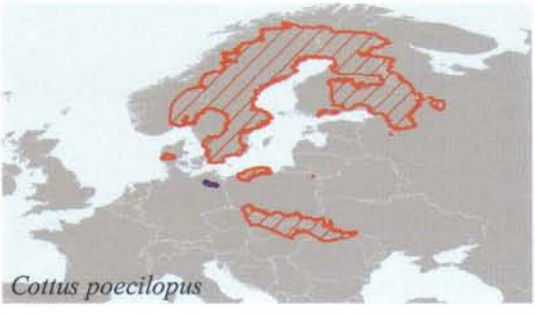
Habitat. Small streams to medium-sized rivers.

Biology. Lives up to 6 years. Spawns for the first time at 1 year. Spawns in March – April. Females spawn once a year in Belgium; up to four times, in February – early July, in stream Bere (southern England). Most individuals spawn 2–3 seasons. They lay adhesive eggs in a compact clutch on ceiling of small cavities in gravel or rock bottom. Males guard eggs until hatching. Males may guard egg clutches of several females. Feeds on a wide variety of benthic invertebrates.

Conservation status. LC. Common in England, very few fragmented populations in Belgium and France, several of them threatened by pollution, water abstraction and alteration of river morphology.

Remark. The invasive population in the Rhine is molecularly and morphologically intermediate between *C. perifretum* and *C. rhenanus* and it

Cottus petiti



Cottus poecilopus

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Peripheral isolation or peripatric speciation

Frequently, isolated populations at the edge of the range of a widely distributed species differ morphologically and/or ecologically. These peripheral populations may eventually diverge and form distinct species. The evolutionary history of these peripheral species is often associated with colonisation of islands, lakes, isolated river basins, mountains or caves. The allopatric speciation model suggests that speciation proceeds faster in peripheral populations because they are small, whereas the wider-ranging central population exhibit much slower evolutionary changes. This might be due to different ecological factors, natural selection, founder effect, etc. In European waters there are several cases of a wide-ranging species in central and northern Europe with a fringe of peripheral species along its southern edge, among others in the genera *Gobio*, *Phoxinus*, *Cobitis* and *Cottus*.

Although these peripheral species are distinguished by morphological and often ecological characters, molecular studies often fail to recognise them as sister species of the central species because of conceptual bias. The relationships between a peripheral species and the geographically adjacent population of the central species is usually closer than the relationships between this adjacent population and the remaining populations of the central species. This situation, however, cannot be recovered by the molecular approaches in current use because they are designed to construct dichotomic relationships, with the assumption that the ancestor species does not survive speciation and is replaced by two daughter-species. Empirical observation suggests that in most cases the central (ancestral) species remains unchanged while the peripheral species diverge. It has yet to be integrated into mainstream procedures that the dichotomy principle should be used with caution in species-level analyses.

Further reading. Mayr, 1970 (allopatric speciation); Wiley & Mayden, 1985 (speciation modes); Kulkarni et al., 1999 (speciation model).

forms a distinct genetic group across its whole expansion range. Hybrids seem to have originated in the lower Rhine in the Netherlands. The parent species apparently came into contact through the man-made connection between the Scheldt and Rhine drainages. It seems to have an unique ecological potential that facilitates the colonisation of large river lowland habitats that were not previously occupied by other *Cottus* species.

Further reading. Volckaert et al., 2002 (genetics); Knapen et al., 2003 (genetics); Persat, in Keith & Allardi, 2001: 340 (biology); Freyhof et al., 2005a: 144 (systematics, description); Nolte et al., 2005 (hybrid invasion).

Cottus petiti

Common name. Lez sculpin.

Diagnosis. Distinguished from other species of *Cottus* in western Europe by: ○ no transverse bands on pelvic / ○ in juveniles and adults, prickling on body extending backward to caudal peduncle / ● last anal ray attached to caudal peduncle on its entire length / ● posterior membrane of second dorsal reaching almost to caudal origin / ○ last dorsal ray reaching backward to rudimentary caudal-fin rays / ○ 15–16½ rays in second dorsal fin / ○ 11–12½ rays in anal fin. Size up to 41 mm SL.

Distribution. France: sources of stream Lez, near Montpellier.

Habitat. Cold, karstic spring.

Biology. Most individuals live 1–2 years. Spawns for the first time at 1 year. Spawns one clutch every 3–4 weeks in the laboratory while in the wild the spawning season extends from November to July.

Conservation status. VU D2.

Further reading. Băcescu & Băcescu-Mester, 1964 (description); Persat et al., 1996 (reproduction); Kottelat, 1997: 170 (systematics); Eppe et al., 1999 (genetics); Freyhof et al., 2005a: 142 (systematics, description).

Cottus poecilopus

Common name. Siberian sculpin.

Diagnosis. Distinguished from other species of *Cottus* in central and eastern Europe by: ● prickles spade-shaped / ● 5–15 distinct transverse bands on pelvic / ● 2 chin pores / ○ lateral line clearly above midline of body; at vertical of 10th ray of second dorsal distance from dorsal midline to lateral line 1.5–2.1 times in distance from ventral midline to lateral line / ○ lateral line incomplete, usually reaching to anal base / ○ prickling restricted to body below pectoral. Size up to 120 mm SL.

Distribution. Streams in Carpathians draining to Danube, Dniestr, Vistula and Odra. Baltic basin, especially in northern Sweden and Finland between 64 and 68°N, central Finnish lakes area, a few streams in southern Finland and northern Poland, Lake Ladoga and southern Lake Onega ba-

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Cottus poecilopus; Tisza, Danube drainage, Hungary; ~90 mm SL. Z. Sallai

Cottus rhenanus; lower Rhine drainage, Germany; ~85 mm SL.

sins, a few lakes in northern Germany (extirpated), Lake Hańcza (Poland) and Skjernaa drainage (Denmark). In Siberia from River Ob eastward to Lena. Absent in rivers draining to Baltic Sea south of Iijöki drainage in central Finland and in rivers draining to the White and Barents Seas.

Habitat. Northern, and mountain and foothill streams, oligotrophic lakes. In Carpathian streams usually more upstream than *C. gobio*, very rarely syntopic.

Biology. Lives up to 6 years. Spawns for the first time at 2–4 years, about 40 mm SL. Spawns in February – April, when temperature rises above 5°C. Females spawn once a year. Most individuals spawn 2–3 seasons. They lay adhesive eggs in a compact clutch on ceiling of small cavities in gravel or rock bottom. Males guard eggs until hatching. Males may guard egg clutches of several females. Nocturnal, shifts to day-activity during winter in the Arctic. Feeds on a wide variety of benthic invertebrates.

Conservation status. LC. Extirpated in Germany.

Remarks. *Cottus* populations from the Kolyma, Amur and Korean drainages usually identified as *C. poecilopus* belong to other species.

Further reading. Bauch, 1970 (biology); Smirnov, 1986 (biology); Freyhof et al., 2005a: 167 (description, systematics).

Cottus rhenanus

Common name. Rhine sculpin.

Diagnosis. Distinguished from other species of *Cottus* in North Sea basin by: ○ prickling on body absent or only under pectoral / ○ first dorsal low, with straight or slightly rounded distal edge in males larger than 60 mm SL (Fig. 81d) / ○ first dorsal with faint black blotch between base of rays 1–3 in males / ○ lateral line complete. Distinguished from *C. gobio* by unique molecular markers. Size up to 96 mm SL.

Distribution. Rhine and Meuse drainages, in Rhine upriver (southward) to about Mannheim, including tributaries of Main and Neckar.

Habitat. Small, cold streams with gravel bottom.

Biology. Spawns for the first time at 2–4 years. Spawns in March – April, when temperature rises above 12°C. Females spawn once a year. Most individuals spawn 2–3 years.

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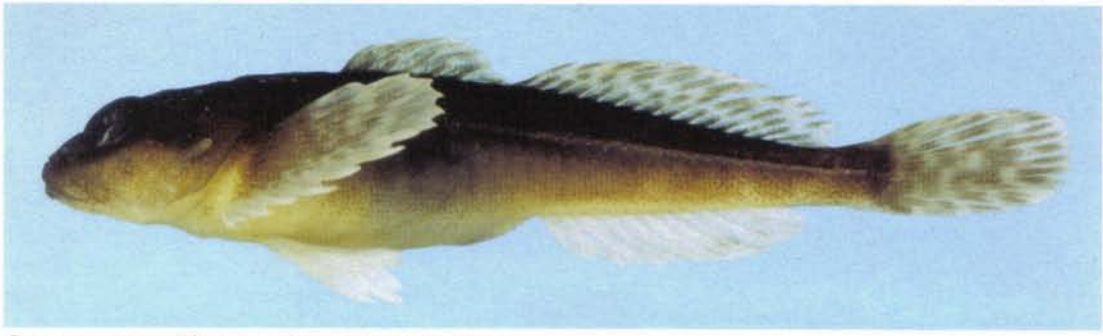
Cottus rondeleti; Hérault drainage, France; 56.5 mm SL.



Cottus scaturigo; Timavo spring, Italy; 44 mm SL.

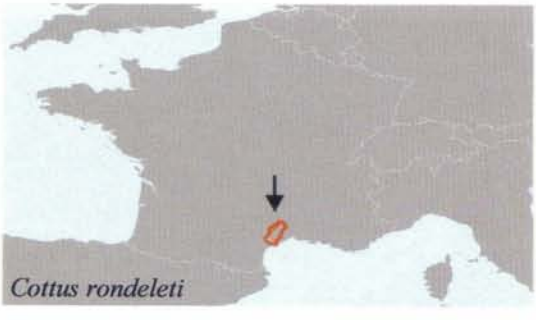
Conservation status. LC.
Remarks. Although *C. rhenanus* can be distinguished from any *C. gobio* populations adjacent to its distribution, it can at present be diagnosed from *C. gobio* as a whole only by the shape of the first dorsal and by molecular characters. Further work on *C. gobio* is likely to show it comprises several distinct lineages and once this is resolved, *C. rhenanus* may become identifiable also by other characters. The population of River Main has mitochondria of *C. gobio*.
Further reading. Freyhof et al., 2005a: 148 (description).

Cottus rondeleti

Common name. Hérault sculpin.
Diagnosis. Distinguished from other species of *Cottus* in western Europe by: ● 10–11½ anal rayss / ○ 14–16 rays in second dorsal fin / ○ no transverse bands on pelvic / ○ lateral line complete, with 29–31+1 pores / ○ 13 pectoral rays / ○ no prickling on body / ○ first and second dorsals slightly joined (Fig. 81b) / ○ snout pale / ○ first dorsal with very dark base. Size up to 60 mm SL.
Distribution. France: three disjunct populations in Hérault drainage.
Habitat. Small stream with clear, swift water and stone bottom.
Biology. No data. Probably similar to *C. gobio*.
Conservation status. CR B1ab(ii,iii) + 2ab(ii,iii).
Further reading. Eppe et al., 1999 (genetics); Freyhof et al., 2005a: 140 (description).

Cottus scaturigo

Common name. Timavo sculpin.
Diagnosis. Distinguished from other species of *Cottus* in Adriatic basin and Danube drainage by: ● body colouration uniform reddish brown, or with markings slightly darker than background / ○ fins hyaline or dusky and rays slightly tessellated / ● first dorsal dark brown to black with bold whitish margin in live nuptial males / ● usually 11½ anal rays / ○ pelvic base attached to body by a small membrane / ○ last anal ray attached to



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Cottus scaturigo; Timavo spring, Italy; ~40 mm SL (flank injured behind pectoral).

Cottus transsilvaniae; Arges, Danube drainage, Romania; 92 mm SL.

body at base only / ○ first dorsal reaching second dorsal (Fig. 81d) / ○ no prickling on body. Size up to 60 mm SL.

Distribution. Italy: Timavo spring, north of Trieste. Timavo spring is the resurgence of River Reka, which flows from Slovenia after 35 km of underground course through the Kras (Karst) plateau. There is no record of *Cottus* species in Reka.

Habitat. Large, very cold spring.

Biology. Spawns for the first time at 1 year. Spawns in March. Most individuals live only 1–2 years.

Conservation status. VU D2.

Further reading. Freyhof et al., 2005a: 152 (description).

Cottus transsilvaniae

Common name. Arges sculpin.

Diagnosis. Distinguished from other species of *Cottus* in Danube drainage by: ○ dorsal head length 19–20 % SL, lateral head length 24–27 % SL / ○ predorsal length 29–30 % SL / ○ distance from tip of snout to origin of second dorsal 47–50 % SL / ○ no transverse bands on pelvic / ○ no prickling on body / ○ usually 18–19 rays in second dorsal / ○ 12–13½ anal rays. Size up to 97 mm SL, might grow larger.

Distribution. Romania: Danube drainage: upper Arges. May be present in other tributaries of lower Danube.

Habitat. Known from a cold and fast-flowing stream.

Biology. No data.

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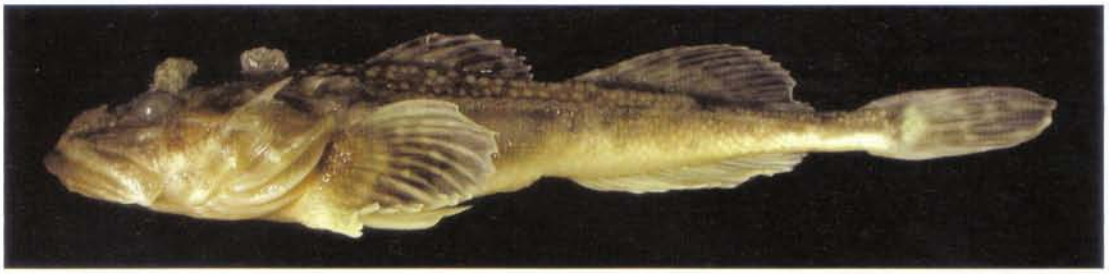


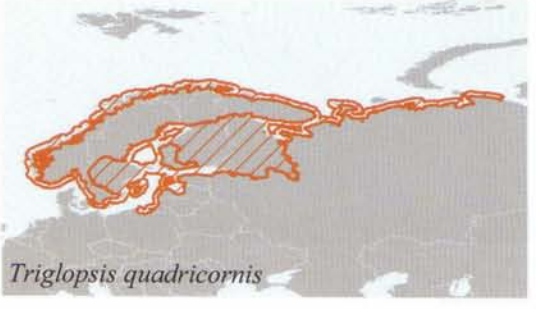
Triglopsis quadricornis; Baltic Sea, Sweden; 140 mm SL. B. Delling

Triglopsis quadricornis; Lake Borken, Sweden; 106 mm SL. B. Delling

Conservation status. DD.
Further reading. Freyhof et al., 2005a: 157 (description).

Triglopsis quadricornis

Common name. Four horned sculpin.
Diagnosis. Distinguished from other species of Cottidae in European freshwaters by: ● branchiostegal membranes forming a free fold across isthmus (Fig. 80a) / ● 4 spongy tubercles on head (weakly developed or absent in some lacustrine populations). Size up to 370 mm SL (estuarine populations), often much smaller in lacustrine populations.
Distribution. Baltic coast of Sweden, Finland, Russia and southwestward to eastern Poland. Western coast of Sweden to northern coast of Norway, eastward to White and Barents Sea basins. In Siberia eastward to about Anadyr estuary. Northern North America. Landlocked populations in Sweden, central Finland and Karelia.
Habitat. Cold brackish and moderately saline water near coast; enters coastal rivers up to 200 km inland. Also landlocked in lakes. Spawns in shallow waters.
Biology. Diurnal in winter, largely nocturnal in summer. Lives up to 14 years. Spawns for the first time at 3–5 years. Males are territorial. Spawns on ceiling of small cavities in gravel or rock bottom. Males guard eggs until hatching. After spawning, female leaves the nest. Juveniles move to shallow water in autumn and again to deeper water in spring, where they remain in summer. Feeds on invertebrates and fishes.
Conservation status. LC, but landlocked populations locally threatened.
Remarks. Earlier called *Myoxocephalus quadricornis* and *Oncocottus quadricornis*.
Further reading. Neyelov, 1979: 115, 131 (systematics); Fedorov, in Whitehead et al., 1986: 1260 (description); Delling, in Kullander, 1999 (variation).



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Family Moronidae

Basses

The family includes 2 genera, *Morone* with 4 species in North America and *Dicentrarchus* with 2 species in Eastern Atlantic and Mediterranean. They are distinguished by having two narrowly separated dorsal fins, 2 opercular spines, a lateral line extending almost to the posterior margin of the caudal fin, and auxiliary rows of lateral line scales on the caudal fin above and below the main row. Species of Moronidae were earlier placed in Serranidae or Percichthyidae. Some authors place the species of *Dicentrarchus* in the genus *Morone*.

The two East Atlantic species are reported to enter brackish waters in Europe. Only *Dicentrarchus labrax* is known definitely from freshwater habitats, whereas *D. punctatus* enters brackish waters only occasionally on the Atlantic coasts of France and the Iberian Peninsula, the Mediterranean and the western Black Sea. At some time, the American *Morone saxatilis* was farmed in southern Russia and Ukraine, but it no longer seems to be cultivated there and stocked or escaped fish have not established populations; isolated individuals may still occur. *M. saxatilis* can be distinguished from *Dicentrarchus* species by having small serrations along the lower part of the preoperculum, directed downward (vs. forward) and 5–7 lateral stripes (vs. body plain or spotted). *Dicentrarchus* is distinguished from superficially similar *Sander* species and (introduced) *Micropterus salmoides* by the presence of spines on the lower part of the preoperculum (vs. smooth preoperculum), the presence of auxiliary rows of lateral line scales on the caudal fin (vs. absence), the concave posterior margin of the anal (vs. convex in *Micropterus*) and 3 anal spines (vs. 2 in *Sander*).

Recently, hybrids between female *Morone saxatilis* and male *M. chrysops* have been used in aquaculture in Italy and Germany; they are likely to escape sooner or later. The hybrids are fertile but produce only few offspring.

Further reading. Johnson, in Moser et al., 1984 (phylogeny); Pickett & Pawson, 1994 (biology); Müller-Belecke & Zienert, 2006 (*Morone* aquaculture).

Dicentrarchus labrax

Common name. Sea bass.

Diagnosis. Distinguished from *D. punctatus* by: 65–80 lateral line scales on body (vs. 58–68) / adults without small black spots on upper part of body (vs. with black spots) / vomerine teeth in an anchor shape patch (crescentic band with a median posterior extension (Fig. 84) (vs. crescentic band only) / scales in interorbital area cycloid (vs. ctenoid). Size up to 1000 mm SL.

Distribution. All European coasts. Absent from White, Barents, Baltic and Caspian Seas.

Habitat. Coastal waters and estuaries.

Biology. Lives up to 30 years. Spawns for the first time at 4–7 years and about 350 (males) and 420 (females) mm SL. A pelagic spawner in open sea, in January – June at temperatures above 9°C. Larvae planktonic. Juveniles move inshore as they grow, aggregating in brackish estuarine nursery areas where they usually remain until their sec-

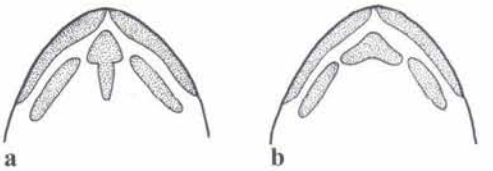

Figure 84 Vomerine teeth patches in *Dicentrarchus* species. **a,** *D. labrax*; **b,** *D. punctatus* (after Bauchot & Pras, 1980).

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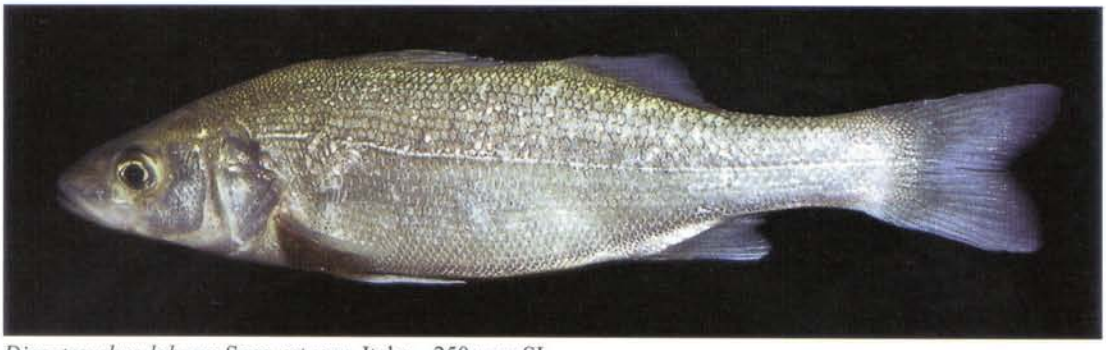
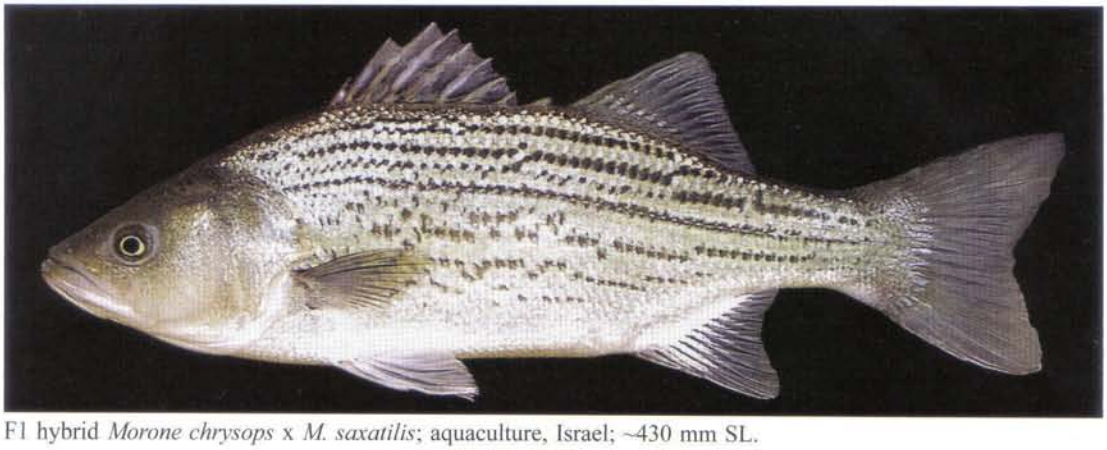


Dicentrarchus labrax; Soca estuary, Italy; ~250 mm SL.



F1 hybrid *Morone chrysops* x *M. saxatilis*; aquaculture, Israel; ~430 mm SL.

ond summer. Large juveniles and adults show a complicated migration pattern at sea, coming close to shore and entering freshwaters of estuaries during summer to forage. Juveniles feed on invertebrates, taking increasingly more fish with age. Adults piscivorous.

Conservation status. LC.

Further reading. Whitehead & Wheeler, 1966 (systematics); Bauchot & Pras, 1980: 252 (diagnosis); Pickett & Pawson, 1994 (biology).

Upper Dniestr, Ukraine; habitat dominated by rheophilic species, such as *Barbatula barbatula*, *Barbus carpathicus*, *B. waleckii*, *Chondrostoma nasus*, *Romanogobio kesslerii* and *Cottus microstomus*.

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Family Centrarchidae

Sunfishes

A small family with about 30 species in eight genera native to North America from Alaska to southern Mexico. In Europe, they are distinguished from the (introduced) Cichlidae by having a single continuous lateral line (vs. lateral line interrupted, anterior part higher on body than posterior part) and absence of pharyngeal tooth plates (vs. presence). They are distinguished from Percidae by having 2–6 anal spines (vs. 1–2), and from *Dicentrarchus* (Moronidae) by the absence of auxiliary rows of lateral line scales on the caudal fin (vs. presence) and from both by having only a single dorsal fin (vs. 2, except *Gymnocephalus*).

Six species of Centrarchidae are reported as introduced in European waters. In fact, only three are established. The remaining three had been introduced, deliberately or accidentally, into single ponds or lakes, lived there for some years, and then disappeared. They are, therefore, not part of the European fish fauna. In case some of these might have survived unnoticed for some time, the key below should facilitate their identification. The introduction of additional species cannot be ruled out.

Further reading. Page & Burr, 1991 (identification); Jenkins & Burkhead, 1993 (identification).

Key to Centrarchidae once recorded from European waters

In species of *Lepomis*, the earflap (Fig. 85) is the posterior projection of the opercle, which usually bears a conspicuous black mark.

1a – Anal spines 5–6; conspicuous red eyes (in life). ..... *Ambloplites rupestris*

1b – Anal spines 3–4; no conspicuous red eyes. 2

2a – 58–81 lateral line scales on body. 3

2b – 35–55 lateral line scales on body. 4

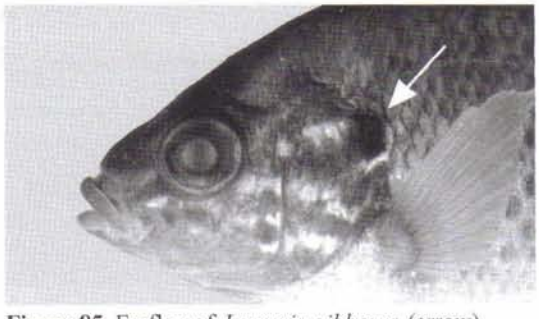

Figure 85 Earflap of *Lepomis gibbosus* (arrow).

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Ambloplites rupestris; Missouri, U.S.A.; 102 mm SL. D. Neely

3a – 58–68 lateral line scales; one bold irregular midlateral stripe or series of closely set blotches. ..... *Micropterus salmoides*

3b – 68–81 lateral line scales; body with narrow bars, often weakly developed. ..... *Micropterus dolomieu*

4a – Posterior part of dorsal and anal with a dark mark; mouth large, upper jaw length greater than eye diameter. ..... *Lepomis cyanellus*

4b – Posterior part of dorsal and anal without dark mark; mouth small, upper jaw length about equal to eye diameter. 5

5a – Ear flap very long, narrow, its depth not greater than eye diameter, tip black, without coloured margin. ..... *Lepomis auritus*

5b – Ear flap short, its depth greater than eye diameter, tip black with a red or orange spot and a light margin. ..... *Lepomis gibbosus*

Ambloplites rupestris

Common name. Rock bass.

Diagnosis. Distinguished from other species of Centrarchidae introduced to Europe by: ● 5–6 anal spines / ● in life, conspicuous red eyes. Size up to about 270 mm SL.

Distribution. Native to North America, in Great Lakes, St. Lawrence, southern Hudson Bay and Mississippi drainages. Widely introduced in North America. Introduced to Europe (France, England, Germany) in the 1880–1910s but did not become established, except for two populations in middle Loire drainage near Digoin and Décize (France).

Habitat. In a wide variety of slow-flowing to stagnant waters, such as large rivers, lakes, ponds, canals and backwaters. Avoids swift waters. Habitats in Loire: main river and lower course of main tributaries, at base of steep banks.

Biology. Lives up to 12 years. Spawns for the first time at 2–3 years. Spawns in April – July, at 15–27°C. Both sexes spawn several times each summer. Males fan and defend nests, which are shallow depressions in sand or gravel bottom along shallow shores. A male may spawn with several females in one nest and guard the nest until abandoned by the larvae. Feeds on a wide variety of invertebrates and small fish.

Conservation status. Alien.

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Lepomis gibbosus; Neretva delta, Croatia; ~100 mm SL.

Further reading. Jenkins & Burkhead, 1993: 699 (biology); Keith & Allardi 2001: 320 (presence in France).

Lepomis gibbosus

Common name. Pumpkinseed.

Diagnosis. Distinguished from other species of Centrarchidae introduced to Europe by: ● ear flap short, about as wide as eye, black with red or orange spot and light margin / ○ 3–4 anal spines / ○ 36–47 lateral line scales on body / ○ posteroventral part of dorsal and anal without dark mark / ○ mouth small, upper jaw length about equal to eye diameter. Size up to about 320 mm SL.

Distribution. Native to North America, in Great Lakes, St. Lawrence and upper Mississippi drainages and Atlantic basin. Widely introduced in temperate waters, in Europe in 1880s as pond and aquarium fish. Now widespread throughout Europe, from Portugal to southern Ukraine, eastward to Dniepr. Especially abundant in Mediterranean countries.

Habitat. A wide variety of slow-flowing to still waters, such as large rivers, lakes, ponds, canals and backwaters. Avoid swift waters. In estuaries with a salinity up to 18.2 ‰.

Biology. Lives up to 8 years. Spawns for the first time at 1–3 years. Spawns in April – June, when temperatures reach 16–18°C. Males fan and defend nests, which are shallow depressions in sand or gravel bottom along shallow shores. Nests in colonies in sunny open habitats. Each males may spawn with several females in one nest and guard the nest until abandoned by larvae. Feed on a wide variety of invertebrates.

Conservation status. Alien.

Further reading. Jenkins & Burkhead, 1993: 749 (biology).

Micropterus salmoides

Common name. Largemouth bass.

Diagnosis. Distinguished from other species of Centrarchidae introduced to Europe by: ● 55–68 lateral line scales on body / ● one prominent lateral stripe or series of closely set blotches / ○ 3 anal spines / ○ mouth large, upper jaw length greater than eye diameter. Size up to about 650 mm SL.

Distribution. Native to North America, in Great Lakes, St. Lawrence and Mississippi drainages, Gulf of Mexico and southern Atlantic basins. Introduced in 1883 to England, Scotland, Germany and Netherlands, then spread throughout Europe. Today extirpated in Great Britain, Germany and Netherlands, but widespread in Mediterranean countries as Portugal, Spain (including Mallorca), southern France, Italy, Switzerland (Ticino) and Adriatic basin from Slovenia to Albania. Also in Slovenian Danube drainage, lakes of Carynthia (Austria). Introductions to Russia failed.

Habitat. A wide variety of slow-flowing to still water bodies, such as large rivers, lakes, canals and backwaters. Avoids fast-flowing waters. In estuaries with a salinity up to 13 ‰.

Biology. Lives up to 16 years. Spawns for the first time at 1–4 years. Spawns in April – June, when temperatures reach 16–18°C. Males fan and defend nests, which are shallow depressions in sand or gravel bottom. Males or both sexes guard nests and free swimming larvae for a few days. Juve-

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Micropterus salmoides; aquaculture, Germany; ~120 mm SL.

niles feed on invertebrates, taking increasingly more fish with age. Adults are piscivorous.

Conservation status. Alien. Responsible for decline of several species of endemic Cyprinidae in Spain.

Remarks. *M. dolomieu* is frequently reported as introduced in European waters. Seven individuals were imported in 1883 to Germany together with *M. salmoides*. They were breed and distributed to local fish farmers but the species soon disappeared as the farmers felt that *M. salmoides* was more promising. There are no later records of *M. dolomieu* in Europe and the species has never been recorded from natural waters.

Further reading. Jenkins & Burkhead, 1993: 732 (biology); Boschung & Mayden, 2004: 470 (biology).

Stream Vâlsan, Romania; last surviving habitat of *Romanichthys valsanicola*.

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Family Percidae

Perches

A family of predominantly freshwater fishes with about 180 species in 10 genera native to Europe, northern and central Asia and North America. Most species belong to the American subfamily Etheostominae (darters: about 160 species in 4 genera). Three genera are endemic to Europe; they are most diverse in the Black Sea basin. Percidae are distinguished from the (introduced) Cichlidae by having a single continuous lateral line (vs. lateral line interrupted, anterior part higher on body than posterior part), from the (introduced) Centrarchidae by having 1–2 anal spines (vs. 3–6), and from *Dicentrarchus* (Moronidae) by having 1–2 anal spines (vs. 3) and no auxiliary rows of lateral line scales on the caudal fin (vs. presence).

All but one of the European Percidae inhabit freshwaters during at least a part of their life. *Sander marinus* is the only species not reported to enter pure freshwaters, inhabiting marine and brackish estuaries, for which reason it is included only in the key; it seems close to extinction and has reportedly not been seen in the past 15 years. Species of *Sander* and *Perca*, and locally *Gymnocephalus*, are commercially important food fishes. *S. lucioperca* has been stocked throughout Europe, Northern Africa and western Asia to transform 'low value' cyprinid stocks into 'high value' fisheries. As a result, it is widely introduced and responsible for the extinction or near extinction of endemic Cyprinidae and *Cobitis* species in Lakes Beysehir and Egridir (Central Anatolia, Turkey) and possibly also elsewhere.

Key to genera of *Percidae* in Europe

1a – Two dorsals confluent. ..... *Gymnocephalus*

1b – Two distinctly separate dorsals. 2

2a – Pelvic and anal yellow to red; dark blotch on posterior part of first dorsal; 5–8 bold bars on flank, usually Y-shaped. ..... *Perca*

2b – Pelvic and anal whitish to brown; no dark blotch on posterior part of first dorsal; flank with no bar or with 7–20 bars. 3

3a – 35–40 total lateral line scales. ..... *Percarina*

3b – 58–97 total lateral line scales. 4

4a – Body compressed; mouth terminal; air-bladder present. ..... *Sander*

4b – Body spindle-shaped; mouth inferior, horse-shoe shaped; no air-bladder. 5

5a – 10–13½ branched anal rays. ..... *Zingel*

5b – 7½ branched anal rays. ..... *Romanichthys*

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Gymnocephalus acerina; Don, Russia; ~100 mm SL. A. Naseka

Key to species of *Gymnocephalus*

1a – 17–19 dorsal spines. 2

1b – 11–16 dorsal spines. 3

2a – 50–55 + 4–5 lateral line scales; roundish dark spots on body. ..... *G. acerina*

2b – 55–62 + 4–5 lateral line scales; 3 discontinuous dark stripes along flank. ..... *G. schraetser*

3a – Body depth 24–27 % SL; flank yellowish with numerous small, irregular, dark blotches; opercule with 1 spine; angle between posterior dorsal-fin margin and caudal peduncle 115–130°. ..... *G. cernua*

3b – Body depth 27–30 % SL; flank grey with a few large, irregular, dark blotches; opercule with 2–3 spine; angle between posterior dorsal-fin margin and caudal peduncle 90–95°. ..... *G. baloni*

Gymnocephalus acerina

Common name. Don pope.

Diagnosis. Distinguished from other species of *Gymnocephalus* by: ● roundish dark spots on body, mostly in 3 rows, first below dorsal base / ● 50–55 + 4–5 lateral line scales / ○ 17–19 dorsal spines. Size up to 210 mm SL.

Distribution. Basin of northern Black Sea and Sea of Azov: Dniestr, South Bug, Dniepr, Don and Kuban drainages. In Dniepr up to Belarus.

Habitat. Flowing waters, also lakes with clear water; in summer in rapids; over sand and gravel bottom but prefers hard compact sand. Spawns in river stretches with heavy current and sand or gravel bottom.

Biology. Spawns for the first time at 2–3 years, 120–160 mm SL. Spawns in small schools. Female lays slightly sticky eggs in several portions: first at 6–8°C, second at 12–14°C. Eggs hatch in 6–8 days at 14–16°C. Newly hatched larvae first lie on bottom; at 9 days (when pectorals are developed), they actively move to middle water layers and drift downstream. At 12 days (6.5 mm), they start active feeding on small invertebrates in shallow shoreline habitats. A benthic species that aggregates in small schools. Usually crepuscular but feeds also during daytime. In September, starts forming large schools and moves to deeper places and remains inactive until ice melts. Does not migrate for long distances. Feeds mainly on benthic invertebrates (crustaceans, insect larvae, molluscs), rarely on small fish.

Gymnocephalus acerina

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Gymnocephalus baloni; Danube, Hungary; ~80 mm SL.

Conservation status. LC, not threatened but rare in most of its range.
Remarks. The correct spelling is *acerina*, not *acerinus*.
Further reading. Berg, 1949: 1048 (morphology, biology); Aleksandrova, 1976: 77 (biology); Collette & Bănărescu, 1977: 1450 (systematics).

Gymnocephalus baloni

Common name. Danube ruffe.
Diagnosis. Distinguished from other species of *Gymnocephalus* by: ● body depth 27–30 % SL / ○ flank grey with a few large, irregular, dark blotches / ○ 14–16 dorsal spines. Size up to 150 mm SL.
Distribution. Danube (from delta to Germany) and Dniepr (from delta to Kiev) drainages; expected in Dniestr.
Habitat. Open sand and muddy bottom in backwaters, large rivers with moderate current.
Biology. Males reproduce for the first time at 1–2 years, females at 2–3. Migrates from river mainstreams to backwaters to spawn. Nocturnal, benthic, feeding on small invertebrates.
Conservation status. LC.
Further reading. Holčík & Hensel, 1974: 472 (description).

Gymnocephalus cernua

Common name. Ruffe.
Diagnosis. Distinguished from other species of *Gymnocephalus* by: ● body depth 24–27 % SL / ○ flank yellowish with numerous small, irregular, dark blotches / ○ 11–16 dorsal spines. Size up to 200 mm SL.
Distribution. Caspian, Black, Baltic and North Sea basins; Great Britain. North to about 69°N in Scandinavia. In Asia, Aral Sea basin, Arctic Ocean basin eastward to Kolyma drainage. Introduced or invasive in France west of Rhine, northern Italy and northern Great Britain. Introduced to Great Lakes region, North America.
Habitat. Eutrophic lakes, lowland and piedmont rivers. Prefers still or slow-flowing water with soft bottom, without vegetation. Most abundant in estuaries of large rivers, brackish lakes with salinities up to 10–12‰ and reservoirs. Generally increases in abundance with increased eutrophication.
Biology. Females live up to 10 years, males up to 7. Spawns for the first time at 1–3 years, males one year earlier than females. Spawns in March –

Gymnocephalus baloni

Gymnocephalus cernua

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Gymnocephalus cernua; Danube, Hungary; ~70 mm SL.

Gymnocephalus schraetser; Danube, Germany; ~100 mm SL. A. Hartl

May, until July in the north, on a variety of substrates at depths of about 3 m or less. Spawns at temperatures above 6°C in the north and above 10°C in the south. Usually, a single female spawns with several males. Eggs become adhesive on contact with water and stick to stones or plants. Females may spawn intermittently, laying eggs in two or more portions, usually separated by about 30 days in summer. Eggs of first portion are larger than those of second portion. Larvae without, or with only a brief, pelagic larval stage, switching early to benthic life, secretive and solitary, not forming schools. Survival of larvae is poor below 10°C and above 20°C. Crepuscular or nocturnal. The well-developed cephalic lateral line system and tapetum lucidum in eyes makes it an efficient predator at night and in turbid waters. Usually feeds on benthic chironomid larvae and amphipods, which can be detected in the top layers of the substrate by sensory canals on head. Pelagic in coastal lakes and tidal estuaries, feeding on zooplankton and fish. When they coexist in deep lakes, *Perca fluviatilis* and *G. cernua* partly occur at different depths, *G. cernua* being more abundant in deeper layers.

Conservation status. LC.

Remarks. The correct spelling is *cernua*, not *cernuus*.

Further reading. Hölker & Thiel, 1998 (biology); Craig, 2000 (biology).

Gymnocephalus schraetser

Common name. Yellow pope.

Diagnosis. Distinguished from other species of *Gymnocephalus* by: ● 3 discontinuous dark stripes along flank / ● 55–62 + 4–5 lateral line scales / ○ 17–19 dorsal spines. Size up to 250 mm SL.

Distribution. Danube drainage.

Habitat. Open sand and mud bottom of large rivers with moderate current.

Biology. Gregarious, nocturnal. Lives up to 15 years. Spawns for the first time at 2–3 years, 120–

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Perca fluviatilis; Danube drainage, Germany; ~200 mm SL. A. Hartl

Perca fluviatilis; Lake Doiran, Greece; 80 mm SL.

160 mm SL. Spawns in April – June. Usually, a single female spawns with several males. Females attach eggs to stones. Larvae are benthic. Usually crepuscular but feeds also during daytime. Feeds on small invertebrates, especially molluscs.

Conservation status. LC.

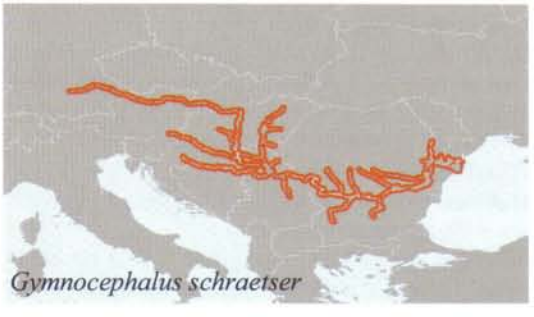
Further reading. Bănărescu, 1964 (distribution); Zauner, 1996 (ecology).

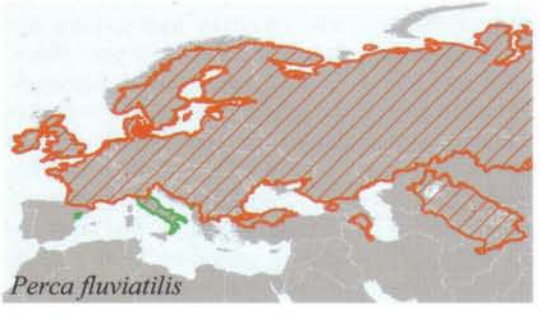
Perca fluviatilis

Common name. Perch.

Diagnosis. Distinguished from other species of Percidae in Europe by: ● pelvic and anal yellow to red / ● dark blotch on posterior part of first dorsal / ● 5–8 bold dark bars on flank, usually Y-shaped / ○ two dorsals, clearly separated from each other / ○ 56–77 total lateral line scales. Size up to 600 mm SL, usually about 200 mm SL, females grow larger than males.

Distribution. Throughout Europe to northernmost extremity of Scandinavia, except Iberian Penin-





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Perca fluviatilis; upper Danube, Germany; female with egg strand, ~150 mm SL. A. Hartl

sula, central Italy and Adriatic basin; Aegean Sea basin: Maritza and from Struma to Aliakmon drainages; Aral Sea basin; in Siberia, in rivers draining to Arctic Ocean eastward to Kolyma (replaced by *P. flavescens* in North America). Introduced in Ebro delta (Spain), central and southern Italy, Lake Skadar (Montenegro, Albania), Amur (Siberia), Australia and South Africa.

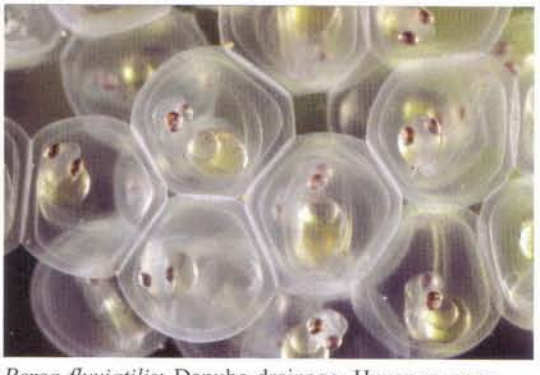
Habitat. A very wide range of habitats from estuarine lagoons, lakes of all types to medium-sized streams.

Biology. Lives up to 21 years, usually to about 6 years. Males reproduce for the first time at 1–2 years, females at 2–4 years. Spawns in February – July, depending on latitude and altitude, when temperature reaches about 6°C. May undertake short spawning migrations. A female usually spawns with several males, once each year. The female circles the spawning site, followed by one male, while other males remain stationary. The egg strand is released as the female swims in spiral clockwise movements, folding herself into a U-shape. All eggs are released and fertilised within about 5 seconds in a single strand, which becomes twisted around and entangled with spawning substrate. Feeding larvae are positively phototactic, live in open water and feed on pelagic organisms. They may be widely distributed by currents. An opportunistic diurnal feeder, preying mainly at sunrise and sunset, using all available prey. Larvae and small juveniles usually prey on planktonic invertebrates. During first summer, many juveniles come near shores to feed on benthic prey. Often becomes piscivorous at about 120 mm SL. Stocks with different life-histories may co-occur in some lakes (littoral, benthic feeding, pelagic zooplanktivorous), sometimes with different spawning sites and times.

Conservation status. LC.

Further reading. Craig, 2000 (biology); Svanbäck & Eklöv, 2002 (morphology).

Perca fluviatilis; Rhine drainage, Germany; egg strand.



Perca fluviatilis; Danube drainage, Hungary; eggs. A. Hartl

Perca fluviatilis; Danube drainage, Hungary; larva in pelagic phase, ~10 mm SL. A. Hartl

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Percarina demidoffii; Danube delta, Romania; 60 mm SL.

Percarina maeotica; Azov Sea, Ukraine; 90 mm SL.

Percarina demidoffii

Common name. Percarina.

Diagnosis. Distinguished from *P. maeotica* by: ● cheek scaleless / ○ body and fin membranes almost transparent / ○ back milky white without dark spots / ○ 8–9 greyish round or irregularly-shaped blotches along base of dorsals. Size up to 100 mm SL.

Distribution. Northwestern Black Sea basin: estuaries and coastal lakes, Danube, Dniestr, South Bug and Dniepr and their lower reaches.

Habitat. Fresh and brackish waters with salinities up to 7 ‰. Abundant at depths around 5 m over black mud.

Biology. A gregarious, bottom-dweller. Spawns in May – June in coastal waters close to river mouths where salinity is low, over mud bottom. Feeds mainly on benthic invertebrates.

Conservation status. NT*. More or less abundant in lower reaches of rivers and coastal lagoons, but may become threatened by increased salinity resulting from reduced flow in all large rivers, which are now dammed.

Further reading. Berg, 1949: 1044 (biology); Vasilieva, 2006 (morphology).

Percarina maeotica

Common name. Azov percarina.

Diagnosis. Distinguished from *P. demidoffii* by: ● cheek scaled / ○ body pigmented / ○ back and flanks grey with numerous dense small dark dots, which may be fused into larger spots along base

Percarina demidoffii

Percarina maeotica

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Tapetum lucidum

Species of *Gymnocephalus*, *Sander* and *Zingel* possess a retinal tapetum lucidum. The tapetum lucidum is a reflective material found in the dorsal two-thirds of the pigmented epithelial layer of the retina. The presence of a tapetum lucidum aids vision in low-light conditions. Light is reflected back and forth between the tapetal processes with additional absorption by the rods after each reflection. **Further reading.** Ali et al. (1977).

Romanichthys valsanicola; Valsan, Danube drainage, Romania; ~90 mm SL. R. Bless

of dorsals. Size up to 100 mm SL.

Distribution. Eastern and northeastern Sea of Azov: Gulfs of Taganrog and Temryuk. Bolshoi Akhtanizovski Liman, Kuban delta, rare in Don delta.

Habitat. Coastal fresh and brackish waters with salinities up to 7 ‰, and river mouths.

Biology. A gregarious, bottom-dweller. Females live up to 4 years, males up to 3. Spawns for the first time at 1 year. Spawns in least saline part of Gulf of Taganrog in June – July, at 24–25°C. Eggs are released over mud bottom; although slightly sticky, they do not adhere to bottom but become coated with minute substrate particles. Soon after spawning, adults migrate to open sea. Eggs hatch in 2 days. Larvae first lie on bottom, moving to the to surface at 4 days. From about 6 mm SL they actively prey on planktonic crustaceans, at 16–40 mm on larger copepods and mysids, and from second the year of life on *Knipowitschia longecaudata, Clupeonella cultriventris*, benthic worms, molluscs, and insect larvae.

Conservation status. LC.

Remarks. The status of this species is not clear. It is retained as valid because of the lack of published data unambiguously demonstrating that it does not differ from *P. demidoffii*.

Further reading. Berg, 1949: 1044 (biology); Vasilieva, 2006 (morphology).

Romanichthys valsanicola

Common name. Asprete.

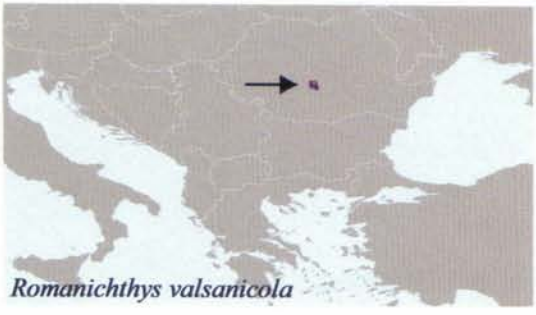
Diagnosis. Distinguished from other species of Percidae in Europe by: ○ 8–9 spines in first dorsal / ○ 58–68 total lateral line scales / ○ mouth inferior, horse-shoe shaped / ○ no air-bladder / ○ two dorsals clearly separated from each other / ○ 7½ branched anal rays. Size up to 110 mm SL.

Distribution. Danube drainage in Romania; formerly known from upper River Arges and its tributaries Vâlsan and Râul Doamnei. Today restricted to 1 km of upper River Vâlsan upstream of Brădet village, but adjacent basins still unsufficiently surveyed.

Habitat. Fast-flowing, cold and clear mountain streams. Usually hidden under stones.

Biology. Nocturnal, bottom dweller. Territorial; possibly spawns in second half of May. 120–150 eggs are deposited under stones. Feeds on insect larvae including mayflies (Ephemeroptera) and stoneflies (Plecoptera).

Conservation status. CR B1ab(ii,iii) + 2ab(ii,iii). Deforestation, construction of roads, extraction of stones and dam constructions have driven this species to the edge of extinction. During construction of a reservoir on River Arges (1965) no water was left in the river downstream of the dam and the species disappeared. In Valsan, the population was seriously impacted by stone extraction from the river, overfishing, pollution and damming of



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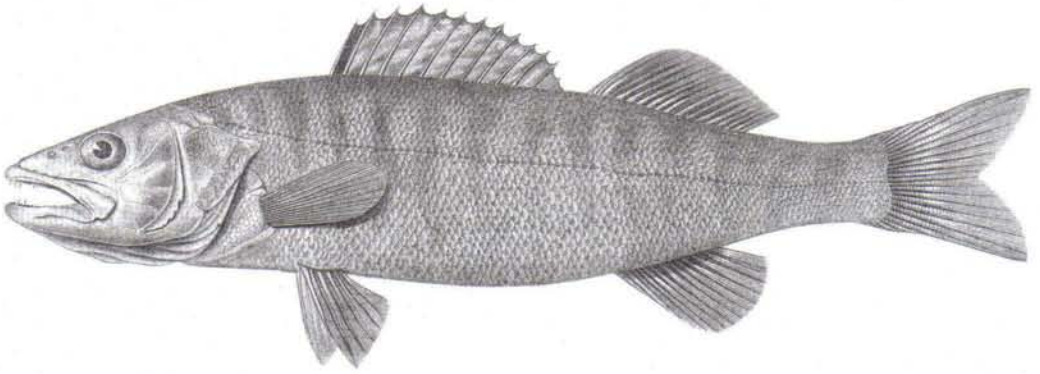


Sander marinus; Russia; ~340 mm SL (marine species, see family introduction). (from Kessler, 1877)

the upper part of river. Survival depends on the continuity of water released by a single reservoir. Presently the focus of a project of the EU Life programme.

Further reading. Dumitrescu et al., 1957: 230 (description); Bănărescu et al., 1995 (biology); Bănărescu, 2002 (conservation).

Key to species of *Sander* in Europe

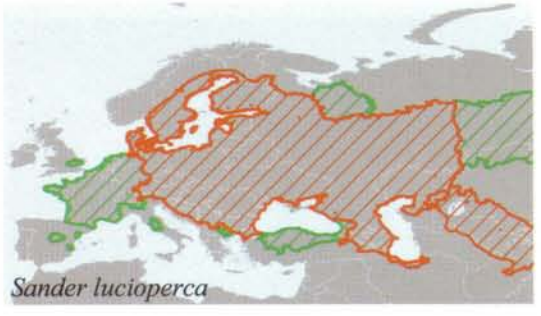
1a – 14–17½ branched rays in second dorsal (Northern Black and Caspian Sea basins; marine). ..... *S. marinus*

1b – 18–22½ branched rays in second dorsal. 2

2a – Canine teeth absent; 70–83 total lateral line scales. ..... *S. volgensis*

2b – 1–2 enlarged canine teeth in anterior part of each jaw; 80–97 total lateral line scales. ..... *S. lucioperca*

Sander lucioperca; Lake Bourget, France; juvenile, 79 mm SL.



Sander lucioperca

Common name. Pikeperch.

Diagnosis. Distinguished from other species of *Sander* in Europe by: ● 1–2 enlarged canine teeth in anterior part of each jaw / ● 18–22½ branched rays in second dorsal / ● 80–97 total lateral line scales. Size up to 1000 mm SL.

Distribution. Caspian, Baltic, Black and Aral Sea basins; Elbe (North Sea basin) and Maritza (Aegean Sea basin) drainages. North to about 65°N in Finland. Introductions began in 1878 in Great Britain, followed by Italy, Strymon drainage (Greece) and continental Europe west of Elbe, Ebro, Tagus and Jucar drainages in Iberian Peninsula, Onega and Severnaya Dvina in White Sea basin. Widely introduced outside Europe in Anatolia, North Africa, Ob and Amur drainages (Asian Russia), Lakes Issyk-kul (Kyrgyzstan), Balkhash and many smaller basins in central Kazakhstan.

Habitat. Large, turbid rivers and eutrophic lakes; brackish coastal lakes and estuaries.

Biology. Lives up to 17 years. Spawns for the first

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Sander lucioperca; Danube drainage, Germany; ~500 mm SL. A. Hartl

Sander volgensis; Danube, Hungary; ~180 mm SL.

time at 3–10 years, usually at 4. Spawns in April – May, exceptional from late February until July, depending on latitude and altitude, when temperatures reach 10–14°C on spawning grounds (lowest temperature for egg incubation 11.5°C). May undertake short spawning migrations. Individuals foraging in brackish water migrate to freshwater habitats (migrations of up to 250 km have been recorded). Homing well developed, even nearby populations may be relatively isolated. Males are territorial and excavate shallow depressions about 50 cm in diameter and 5–10 cm deep in sand or gravel, or among exposed plant roots on which eggs are deposited, usually in turbid water and at 1–3 m depth. Spawns in pairs, at dawn or night. The female remains over the nest while the male circles rapidly around, at about 1 metre from the nest. Then the male takes a vertical orientation and both swim around swiftly, and eggs and sperm are released. The female leaves the nest after all eggs are released. The male defends the nest and fans the eggs with his pectorals. Females spawn once a year. Feeding larvae are positively phototactic and feed on pelagic organisms after they leave the nest for open water. Piscivorous, feeding mostly on gregarious, pelagic fishes.

Conservation status. LC.

Remarks. Earlier knows as *Stizostedion lucioperca* and *Lucioperca lucioperca*.

Further reading. Craig, 2000 (biology); Lappalainen et al., 2003 (biology).

Sander volgensis

Common name. Volga pikeperch.

Diagnosis. Distinguished from other species of *Sander* in Europe by: ● canine teeth absent / ○ 19–21½ branched rays in second dorsal / ○ 70–83 total lateral line scales / ○ cheek scaled. Size up to 400 mm SL.

Distribution. Northern Black Sea basin, from Danube (up to Vienna) to Kuban drainages; Caspian basin (Volga and Ural drainages).

Habitat. Large, turbid rivers and lakes; in brackish coastal lakes and estuaries.

Biology. Lives up to 12 years. Spawns for the first time at 3–4 years and 200–300 mm SL, females

Sander volgensis

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usually a year later than males. Spawns for about one month in April – May, at 10–22°C. Individual females may spawn 2–3 portions of eggs. May undertake short spawning migrations. Males are territorial and excavate shallow depressions in sand or gravel, or exposed plant roots on which eggs are deposited, usually along shallow shores at 1–2 m depth. Nests often close to nests of *S. lucioperca*. Most active at dusk and dawn, foraging on small fish and invertebrates. Larvae and juveniles pelagic, feeding on zooplankton.

Conservation status. LC.

Remarks. Earlier knows as *Stizostedion volgense* and *Lucioperca volgensis*.

Further reading. Evlanov et al., 1998 (description, biology).

Key to species of *Zingel*

1a – 12–15 spines in first dorsal; 2 simple and 15–17½ branched rays in second dorsal. ..... *Z. zingel*

1b – 7–10 spines in first dorsal; 1–2 simple and 9–12½ branched rays in second dorsal. 2

2a – 57–65 + 3–6 lateral line scales. ..... *Z. asper*

2b – 70–85 + 4–7 lateral line scales. 3

3a – Cheek scaleless or at most with 2–6 scales in a single row along posterior lower edge of orbit (Fig. 86a); two opercular spines (Fig. 86a). ..... *Z. balcanicus*

3b – Cheek covered by several rows of scales (Fig. 86b); a single opercular spine (Fig. 86b). ..... *Z. streber*

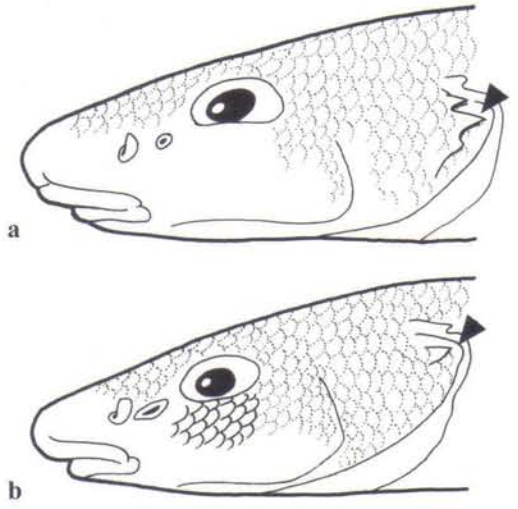

Figure 86 Head of *Zingel* species showing scales on cheek and opercular spines (arrow). **a,** *Z. balcanicus*; **b,** *Z. streber* (after Bănărescu & Nalbant, 1979).

Zingel asper

Common name. Apron.

Diagnosis. Distinguished from other species of *Zingel* by: ● 57–65 + 3–6 lateral line scales / ○ 8–9 spines in first dorsal / ○ 1–2 simple and 9–12½ branched rays in second dorsal / ○ no scales on cheeks. Size up to about 200 mm SL.

Distribution. Rhône drainage, except Lake Geneva basin (France, Switzerland). Originally widely distributed, but following habitat alterations distribution is now much fragmented and restricted. Main subsisting populations in middle Doubs (France, Switzerland) and Durance and Ardèche (southern France).

Habitat. Main course of rivers and large streams, in riffles. On stone bottom. In some sites only in deep water (below 1.2 m) in others in shallow riffles.

Biology. Benthic. Nocturnal. Spawns for the first time at 2–4 years. Spawns in February – April in deeper parts of riffles. Eggs strongly adhesive, 2.2 mm in diameter, deposited on gravel. Eggs hatch in about 14 days at 13°C. Larvae feed on plankton under surface, then (at about 25 mm SL) move to benthic habitats. Feeds on aquatic invertebrates.

Conservation status. CR B2ab(iii).

Further reading. Steinmann, 1938 (morphology); Boutitie, 1984 (distribution); Perrin, 1988 (biolo-

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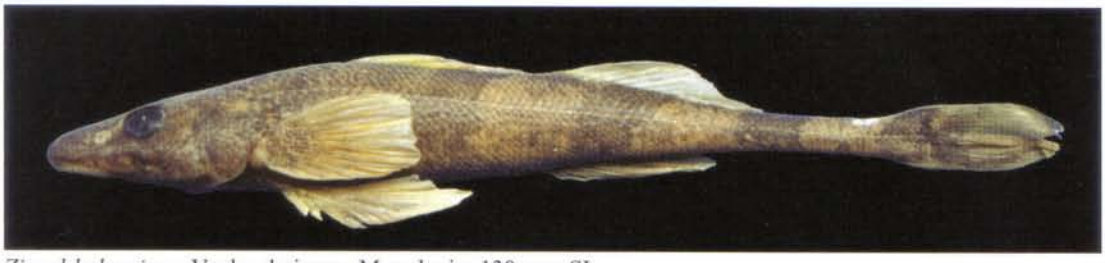
Zingel asper; Ardèche, Rhône drainage, France; ~120 mm SL. M. Roggo



Zingel balcanicus; Vardar drainage, Macedonia; 130 mm SL.

gy); Perrin, in Keith & Allardi, 2001: 314 (biology); Mari, 2001 (biology, conservation); Mari et al., 2002 (conservation); Cavalli et al., 2003 (feeding).

Zingel balcanicus

Common name. Vretenar.

Diagnosis. Distinguished from other species of *Zingel* by: ○ 7–9 spines in first dorsal / ○ 2 simple and 10–12½ branched rays in second dorsal / ○ scales on cheeks absent or restricted at most to 2–6 scales in a single row along posterior lower edge of orbit (Fig. 86a) / ○ 73–83 + 5–6 lateral line scales. Size up to 155 mm SL.

Distribution. Middle Vardar drainage (from Smokvica to Siricino) and its tributary Treska up to Macedonski Brod (Macedonia). No record from Greece, but possibly present downstream as far as Axioupoli.

Habitat. Main river.

Biology. No information. Probably as *Z. streber*.

Conservation status. DD. No record since 1986, possibly extinct.

Further reading. Karaman, 1936: 60 (morphology); Grupče & Dimovski, 1973 (distribution); Bănărescu & Nalbant, 1979: 356 (systematics); Kottelat, 1997: 174 (systematics).

Zingel streber

Common name. Streber.

Diagnosis. Distinguished from other species of *Zingel* by: ○ 7–10 spines in first dorsal / ○ 1–2 simple and 9–11½ branched rays in second dorsal / ● cheeks covered by several rows of scales (Fig. 86b) / ○ 70–85 + 4–7 lateral line scales. Size up to 175 mm SL.

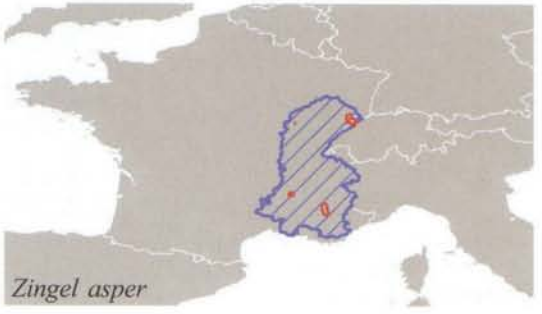
Distribution. Danube and Dniestr drainages.

Habitat. Main course of small to large rivers, in stretches with strong current. On stone bottom.

Biology. Nocturnal, benthic. Spawns in March – May on gravel bottom. Feeds on aquatic invertebrates.

Conservation status. LC.

Further reading. Bănărescu & Nalbant, 1979: 356



Zingel asper

Zingel balcanicus

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Zingel streber; Danube, Austria; ~120 mm SL.

Zingel streber; lower Danube drainage, Romania; ~90 mm SL.

Zingel zingel; upper Danube, Germany; ~300 mm SL. A. Hartl

(systematics); Holčík, 1979 (morphology); Kottelat, 1997: 174 (systematics).

Zingel zingel

Common name. Zingel.

Diagnosis. Distinguished from other species of *Zingel* by: ● 12–15 spines in first dorsal / ● 2 simple and 16–19½ branched rays in second dorsal / ○ no scales on cheeks / ● 82–95 + 4–6 lateral line scales. Size up to 480 mm SL.

Distribution. Danube and Dniestr drainages.

Habitat. Main course of large rivers, in fast-flowing waters.

Biology. Nocturnal, benthic. Spawns in March – April on sand bottom. Single females spawn with several males in a dense spawning group. Eggs very sticky and attached to gravel. Feeds on aquatic invertebrates and small fishes.

Conservation status. LC.

Further reading. Bănărescu, 1964: 686 (biology); Oliva, 1960 (description).

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Family Cichlidae

Cichlids

A large family of mostly small freshwater fishes with about 1400 named (and several hundreds unnamed) species found throughout tropical and temperate Africa, Madagascar, South and Central America and a few in India, Sri Lanka, Iran and the Levant. They are distinguished from superficially similar fishes of the families Percidae, Centrarchidae and Moronidae by a continuous dorsal fin with many spines, an interrupted lateral line (anterior part higher on body than posterior part), nostril with a single naris on each side of head, and a Y-shaped tooth plate on lower pharyngeal bone with numerous teeth. One South American species has been introduced to the Iberian Peninsula; it has established several viable populations. One species from Central America is established in Hungary. Two African species are established in a hot spring near Villach (Austria) and another one in Greece and Italy. Some African species are cultured as food fishes in great quantities throughout the world and in warm aquaculture throughout Europe. *Oreochromis niloticus* has already escaped and *O. aureus*, *O. mossambicus* and *Tilapia zillii* are the most likely candidates to escape from fish farms or to establish local populations in and around hot springs. Numerous other cichlid species are kept by aquarium hobbyists and locally, some species were stocked in hot springs or in warm water effluents of power plants. Cichlids are generally very sensitive to temperatures below 10°C; they die if exposed to such temperature for more than a few hours. Therefore, cichlid populations are usually not able to spread and are killed by cold weather. However, where introduced, cichlids may seriously damage the peculiar ecosystems of hot springs. We include here *Australoheros facetus*, which is well established in natural habitats over a wide area and a further four species with local distributions, mainly in hot springs. Species that have not established sustainable populations, that occur only in warm water effluents of power plants or that were recorded only once are not included. If cichlids are found outside southern Spain and Portugal, the aquarium literature should be consulted for identification.

Further reading. Trewavas, 1983; Stawikowski & Werner, 1998.

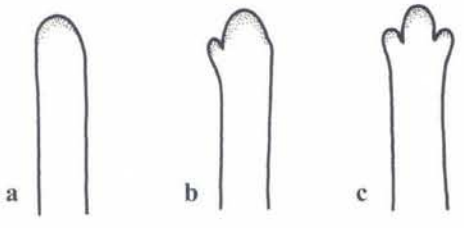

Figure 87 Jaw teeth in Cichlidae: **a,** unicuspid; **b,** bicuspid; **c,** tricuspid (after Trewavas, 1983).

Oreochromis mossambicus; feral, Singapore; male, 108 mm SL (above), and female, 76 mm SL (below).
H. H. Tan

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Australoheros facetus; Mira, Portugal; ~80 mm SL.

Key to species of Cichlidae established or cultivated in Europe

1a – 5–10 anal spines.
..... 2

1b – 3 anal spines.
..... 3

2a – 5–6 anal spines; outer teeth on jaws unicuspid or bicuspid (Fig. 87a–b).
..... *Australoheros facetus*

2b – 10 anal spines; outer teeth on jaws tricuspid (Fig. 87c).
..... *Herotilapia multispinosa*

3a – Outer teeth on jaws unicuspid (Fig. 87a).
..... 4

3b – Outer teeth on jaws bicuspid (Fig. 87b).
..... 5

4a – 5 dark blotches or bars on flank, first one confluent with opercular spot, last one on caudal base.
..... *Hemichromis fasciatus*

4b – 3 dark blotches on flank, first one on opercle, last one on caudal base.
..... *Hemichromis guttatus*

5a – 8–11 gill rakers.
..... *Tilapia zillii*

5b – 16–26 gill rakers.
..... 6

6a – Regular grey or black bars extending across whole caudal.
..... *Oreochromis niloticus*

6b – Caudal without regular bars.
..... 7

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Hemichromis fasciatus; Freetown, Sierra Leone; ~150 mm SL.

7a – Breeding males greyish or whitish; jaws of mature males not enlarged, lower jaw 29–37 % HL; 18–26 gill rakers.
..... *Oreochromis aureus*

7b – Breeding males black with lower part of head white; jaws of mature males greatly enlarged, lower jaw 32–46 % HL; 16–19 gill rakers.
..... *Oreochromis mossambicus*

Australoheros facetus

Common name. Chanchito.

Diagnosis. Distinguished from other species of Cichlidae introduced to Europe by: ● 5–6 anal spines / ○ outer teeth on jaws unicuspid or bicuspid (Fig. 87a–b). Size up to 250 mm SL.

Distribution. Native to Argentina. First recorded in Mira drainage in 1940, has since invaded Guadiana and Sado drainages (Portugal and Spain). Also introduced in Rio Biobio (Chile).

Habitat. Pools and still water.

Biology. Spawns for the first time at 1–2 years. Spawns when temperatures rise above 28–30°C. Forms pairs; both sexes territorial. Females lay eggs on exposed hard surfaces such as stones or wood. Larvae and juveniles guarded by parents for 1–3 weeks. An opportunistic diurnal feeder, eating detritus and plant material, preying on small aquatic animals, including small fish. Very resistant to low temperatures.

Conservation status. Alien. A threat to native species.

Further reading. Almaça, 1995 (Portugal); Doadrio, 2001: 255 (Spain); Stawikowski & Werner, 1998: 322 (biology, systematics); Říčan & Kullander, 2006 (systematics).

Hemichromis fasciatus

Common name. Five-spot cichlid.

Diagnosis. Distinguished from other species of Cichlidae introduced to Europe by: ● 5 dark blotches or bars on flank, anterior one confluent with opercular spot, posterior one on caudal base / ○ 3 anal spines / ○ outer teeth on jaws unicuspid (Fig. 87a). Size up to 204 mm SL.

Distribution. Native to West Africa, from Senegal to Nigeria, Lake Tchad basin and upper Nile drainage. Introduced around 1970 in a stream fed by hot springs in Villach (Austria).

Habitat. In Africa, in a wide variety of still and slow-flowing water bodies and brackish waters. In Austria, in a small stream fed by hot springs, at 24–29°C.

Biology. Forms pairs. Females lay eggs on exposed hard surfaces such as stones or wood. Larvae and juveniles guarded by both parents for 4–8 weeks. Juveniles prey on invertebrates, adults on fishes.

Conservation status. Alien.

Further reading. Loiselle, 1979: 12 (distribution, systematics); Honsig-Erlenburg, 2001 (Austrian population).

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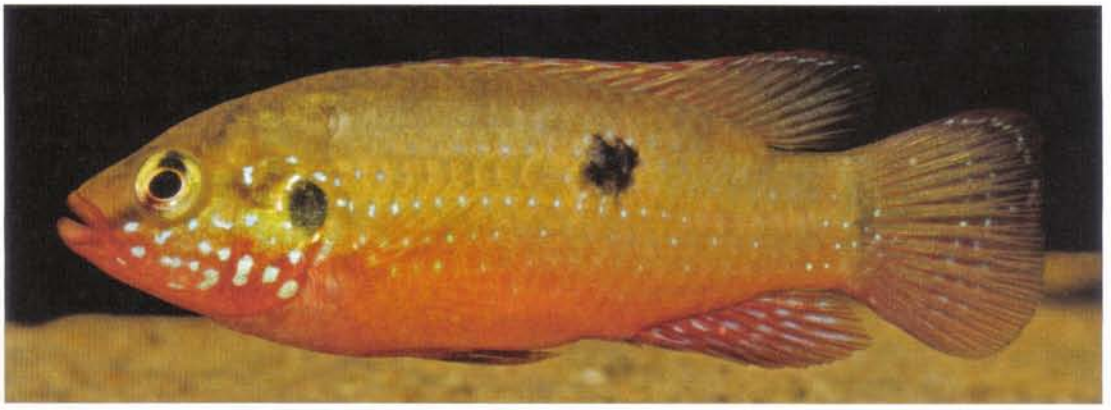

Hemichromis guttatus; Villach, Austria; ~70 mm SL.

Herotilapia multispinosa; aquarium stock; ~70 mm SL.

Hemichromis guttatus

Common name. Jewel cichlid.

Diagnosis. Distinguished from other species of Cichlidae introduced to Europe by: ● 3 dark blotches on flank, anterior one on opercle, posterior one on caudal base / ○ 3 anal spines / ○ outer teeth on jaws unicuspid (Fig. 87a). Size up to 92 mm SL for wild individuals, up to 120 mm SL for aquarium-kept ones.

Distribution. Native to West Africa, from Senegal to Nigeria. Introduced around 1970 in a stream fed by hot springs in Villach (Austria).

Habitat. In Africa, in a wide variety of still and slow-flowing water bodies and brackish waters. In Austria, abundant in a small stream fed by hot springs, at 24–29°C.

Biology. Forms pairs. Females lay eggs on exposed hard surfaces as stones or wood. Larvae and juveniles guarded by both parents for about 4 weeks. Feeds on invertebrates.

Conservation status. Alien.

Remark. This genus is in need of a critical revision.

Further reading. Loiselle, 1979: 74 (distribution, systematics); Honsig-Erlenburg, 2001 (Austrian population).

Herotilapia multipinosa

Common name. Rainbow cichlid.

Diagnosis. Distinguished from other species of Cichlidae introduced to Europe by: ● 10 anal spines / ○ outer teeth on jaws tricuspid (Fig. 87c). Size up to 100 mm SL.

Distribution. Native to Atlantic drainages of Cen-

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Oreochromis niloticus; aquaculture, Singapore; 220 mm SL. H. H. Tan

tral America from Rio Patuca (Honduras) south to Rio Matina (Costa Rica) and Pacific drainages from Rio Guasaule (Nicaragua) south to Rio Tempisque (Costa Rica). Discovered in 1991 in the hot spring at Heviz (Balaton, Hungary) where it is established.

Habitat. Shallow, densely vegetated shores of lakes and slow-flowing rivers, spawns mostly in backwaters and side arms.

Biology. Spawns for the first time at 1 year, maybe earlier. Forms pairs; both sexes territorial. Spawns on vertical surfaces as stones or wood. Produces different sounds when interacting with conspecifics. Larvae and juveniles guarded by both parents for 1–3 weeks. Larvae are transferred to shallow depressions in bottom or, if oxygen concentrations are low, hang by their adhesive head secretions on vertical structures close to water surface. Parents leave spawning territory and follow the foraging flock of larvae and juveniles, defending them in a mobile territory against small predators. Parents warn their offspring by rapid movements of fins wherupon the young gather together below parents. At night, parents regroup larvae and juveniles in a shallow bottom depression. Young of similar size from other couples are often adopted by breeding couples. If the brood is lost, females may spawn again about 2 weeks after first spawning. Tolerant of high temperatures and able to survive in small water bodies during dry periods. Feeds on a wide variety of aquatic plants and small invertebrates.

Conservation status. Alien.

Further reading. Biro, 1997 (introduction); Bussing, 1998: 351 (description); Stawikowski, 2001 (record); Stawikowski & Werner, 1998: 441 (biology, distribution).

Oreochromis niloticus

Common name. Nile tilapia.

Diagnosis. Distinguished from other species of Cichlidae in Europe by: ● 3–40 dark grey to black bars on caudal (number increasing with size) / ● 15–17 dorsal spines / O 3 anal spines / O outer teeth on jaws bicuspid (Fig. 87b). Size up to 395 mm SL.

Distribution. Native to western and eastern Africa, Nile drainage and Israel; hatchery stocks introduced world-wide. Introduced to Greece, in hot springs of Thermopyles (near Lamia) and Kremasta Reservoir (Acheloos drainage) and in northern Italy in a canal with warm industrial effluent.

Habitat. Wide variety of lakes, backwaters and slow-flowing rivers. In Europe in hot springs.

Biology. Non-spawning individuals gregarious along shores. Males form territories and excavate shallow depressions in sandy or muddy shores and try to attract females. The nest is a circular depression up to 100 cm in diameter and 50 cm deep, diameter usually twice length of breeding male. Females come to the nest only to spawn. Eggs are laid in about 20 portions, during a period of 45–120 minutes. They are picked up by the female as they are laid, before, during or after fertilisation.

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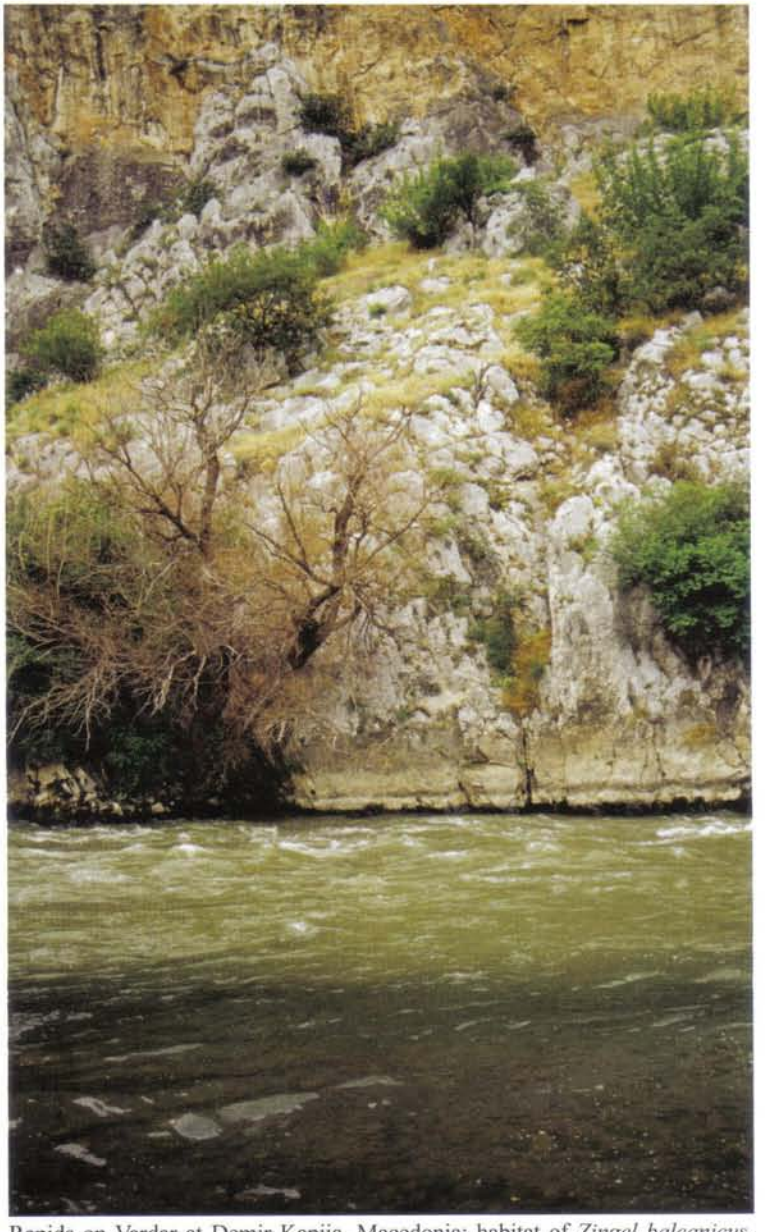
No lasting pair-bond. Females keep eggs and larvae about 20 days in the mouth and guard feeding juveniles up to 2 weeks. Juveniles omnivorous; half-grown and adults mostly feed on planktonic and epilithic blue-green algae, diatoms and macrophytes.

Conservation status. Alien. Populations often explode and stunt. Significant impact on native fishes because of their dense populations and competition for habitat; further, their nesting activity and territorial behaviour disturbs habitat and spawning grounds. Negative impacts blindly ignored by the international and national agencies promoting its stocking.

Remarks. There is no recent information on the status of the introduced populations. The species is cultivated in several countries and escapes are expected.

Further reading. Trewavas, 1983: 140 (description, biology); Economidis et al., 2000a: 246 (introduction).



Rapids on Vardar at Demir Kapija, Macedonia; habitat of *Zingel balcanicus*, *Romanogobio elimeius*, *Barbus macedonicus*, *Chondrostoma vardarense*, *Vimba melanops* and other rheophilic species.

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Family Blenniidae

Blennies

A large family of mostly small marine fishes with about 350 species found throughout the world's tropical and temperate seas, generally in shallow water, on or in rock or stone bottom; a few species have adapted to estuarine and freshwater conditions. They are characterised by pelvics anterior to the pectorals and with only a single spine (embedded in the skin) and 2–4 rays, scaleless skin, numerous comb-like teeth, and long dorsal and anal. Some species can be seen skipping on waves on rocky coasts while feeding on algae. Two species are known from European freshwaters. In addition, *Salaria pavo* is sometimes listed as a freshwater inhabitant. It effectively enters lagoons and brackish waters but has not been recorded from true freshwater habitats and is included here only in the key.

Further reading. Springer, 1968 (systematics); Wirtz, 1976 (key); Bath, 1977 (systematics).

Key to species of *Salaria* in European fresh and brackish waters

1a – A large oval dark blotch behind eye; 2 spines and 23–25 rays in anal; 12 spines and 22–25 rays in dorsal (occasionally in estuaries in brackish water). ..... *S. pavo*

1b – No large oval dark blotch behind eye; 2 spines and 16–19 rays in anal; 12–13 spines and 16–17 rays in dorsal. 2

2a – 3–5 rows of bold black dots on cheek, roughly running diagonally from eye backward and downward, space between lower two rows greyish and spaces between upper rows paler (Fig. 88a); cirrus above eye simple (Fig. 88a); 25–30 teeth in the upper jaw, 20–27 in lower jaw (Lake Trichonis, Greece). ..... *S. economidisi*

2b – A broad diagonal band of tiny dots from lower edge of eye downward backward (Fig. 88b); cirrus above eye branched (Fig. 88b); 16–24 teeth in the upper jaw, 16–20 in lower jaw. ..... *S. fluviatilis*

Salaria pavo; Messolonghi Lagoon, Greece; male, 81 mm SL (left), female, 61 mm SL (right).

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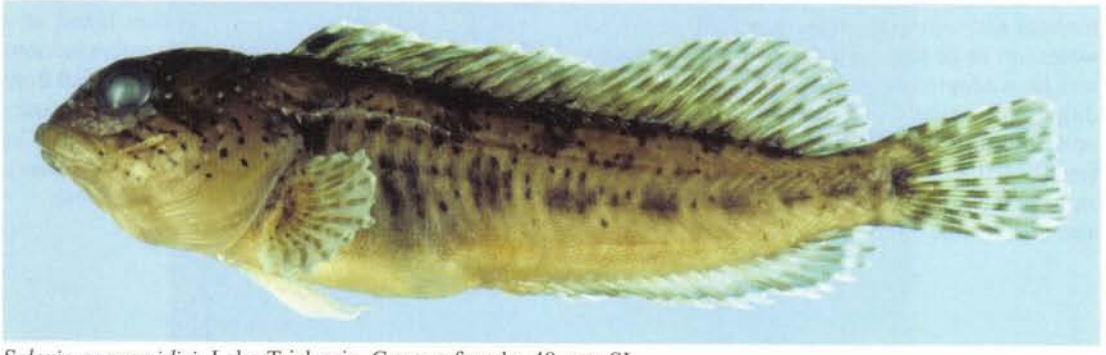
Salaria economidisi; Lake Trichonis, Greece; male, 50 mm SL.



Salaria economidisi; Lake Trichonis, Greece; female, 48 mm SL.

Salaria economidisi

Common name. Trichonis blenny.

Diagnosis. Distinguished from other species of *Salaria* in European inland waters by: ● 3–5 rows of bold black dots on cheek, roughly running diagonally from eye backward and downward, space between two of the lower rows greyish and spaces between upper rows paler (Fig. 88a) / ○ cirrus above eye simple (Fig. 88a) / ○ head length 29–33 % SL / ○ 25–30 teeth in upper jaw, 20–27 in lower jaw / ○ 2 spines and 16–19 rays in anal / ○ 12–13 spines and 16–17 rays in dorsal. Size up to at least 65 mm SL.

Distribution. Greece: Lake Trichonis.

Habitat. Lake shores, usually in dense vegetation at 0.3–2.0 m depth.

Biology. Territorial. Feeds on insects and crustaceans. Spawns in May – July. Eggs hatch in about one week. Larvae are planktonic until about 15 mm.

Conservation status. CR B1ab(i,ii,iii), threatened by water abstraction and land reclamation.

Further reading. Economou et al., 1994a: 29 (lar-

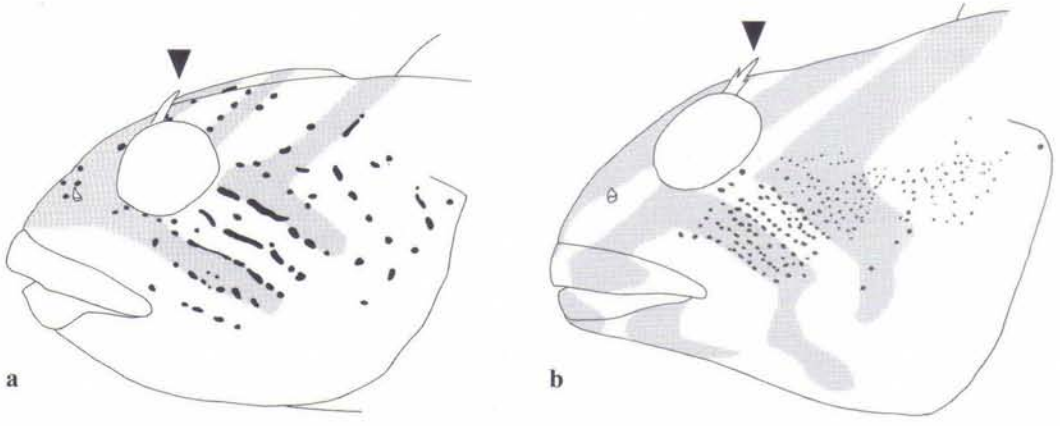


Figure 88 Head pattern and cirrus above eye (arrow) in: **a,** *Salaria economidisi*; **b,** *S. fluviatilis* (after Kottelat, 2004).

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Salaria fluviatilis; Lake Volvi, Greece; nuptial male, ~70 mm SL.

Salaria fluviatilis; Neretva drainage, Bosnia-Herzegovina; female, ~80 mm SL.

vae); Perdices et al., 2000: 723 (genetics); Kottelat, 2004a: 122 (description).

Salaria fluviatilis

Common name. Freshwater blenny.

Diagnosis. Distinguished from other species of *Salaria* in European inland waters by: ● a broad diagonal band of tiny dots from lower edge of eye downward backward (Fig. 88b) / ○ cirrus above eye branched (Fig. 88b) / ○ head length 25–31 % SL / ○ 16–24 teeth in upper jaw, 16–20 in lower jaw / ○ 2 spines and 16–19 rays in anal / ○ 12–13 spines and 16–17 rays in dorsal. Size up to about 130 mm SL.

Distribution. Mediterranean basin in Europe, Turkey, Israel, Morocco and Algeria; Iberian Peninsula: Fluvia, Ebro, Jucar, Segura, Guadiana and Guadalquivir drainages; France: Aude, Rhône (including Lake Bourget; introduced to Lake Annecy around 1980) and Var drainages (presence in Garonne drainage possibly due to invasion through Canal du Midi), Corsica; Italy: most streams with stone bottom, Lakes Garda, Maggiore, Lugano and Mergozzo, Sicily, Sardinia; Croatia, Montenegro, Albania; Greece: Kalamas, Acheron, Acheloos and Aliakmon drainages, Crete, most drainages of Peloponnese, Lakes Doiran, Koronia, Volvi and Vistonis. Sometimes listed as a recent invader of subalpine lakes of Apennine Peninsula, but in fact recorded from Lake Maggiore as early as 1836.

Salaria economidisi

Salaria fluviatilis

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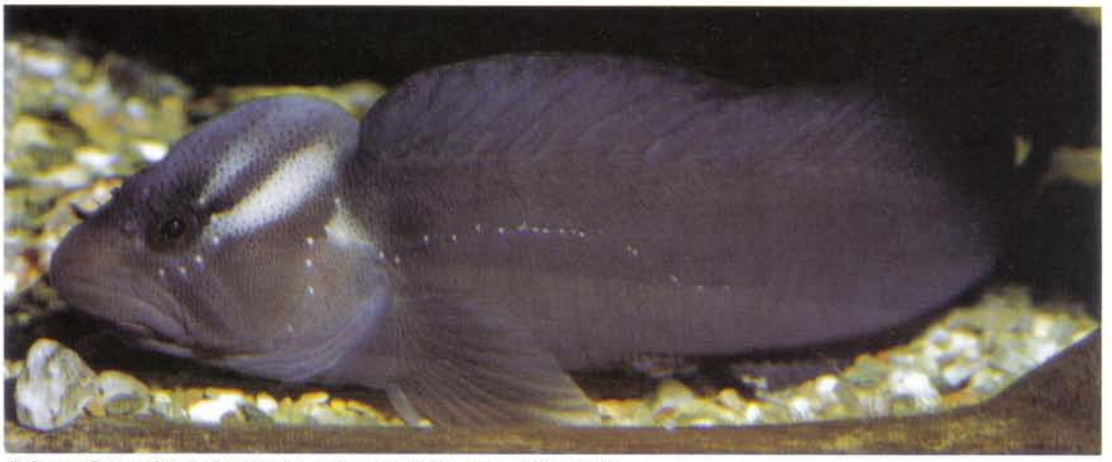

Salaria fluviatilis; Lake Garda, Italy; nuptial male, ~80 mm SL.

Salaria fluviatilis; Lake Garda, Italy; female, ~50 mm SL. A. Hartl

Habitat. Lakes and streams with moderate current and stone bottom; in streams, deepest and fastest microhabitats are preferred; sometimes in coastal lagoons with low salinity.

Biology. Territorial; lives under stones. Lives up to 5 years. Spawns for first time at end of first year. Spawns up to 3 years, but most females die at end of first spawning year. Reproduces in May – August in France, April – July in Spain and Italy, at temperatures above 18°C. Female spawns up to 1200 eggs (usually 200–300) in a single layer under a large stone; spawns several egg portions during a spawning season. Male cleans, fans and defends eggs until hatching. Several females may spawn with one male, which may guard eggs at different stages of development. Eggs hatch in about a week. Larvae are planktonic until about 15 mm, are drifted to and remain in quite pools or side arms of rivers. Feeds on insects, crustaceans and fry.

Salaria fluviatilis, juvenile; Krka, Croatia; ~17 mm SL.

Conservation status. LC*. Most riverine populations have declined in recent years because of habitat alteration (especially siltation and alteration of stream morphology) and predation by exotic species. The presence of habitat suitable for the larval 'pelagic' stage downstream of spawning sites is a limiting factor. Lacustrine populations are apparently safer.

Further reading. Cipria, 1936 (larvae); Wickler, 1957 (behaviour); Freeman et al., 1990 (habitat); Gandolfi et al., 1991: 483 (biology); Ferrito & Tigano, 1996 (threats); Perdices et al., 2000: 723 (genetics); Doadrio, 2001: 252 (biology); Bath, in Miller, 2003: 97 (biology); Kottelat, 2004a (diversity); Vinyoles & de Sostoa, 2007 (biology).

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Family Odontobutidae

Sleepers

A small family of about 15 species of East Asian fishes formerly included in the family Eleotrididae. They are distinguished from the superficially similar fishes of the family Cottidae by the presence of scales (vs. absence) and usually absence of lateral line pores (vs. presence), from the Percidae by having the first dorsal fin without spines (vs. with) and from the Gobiidae by having the pelvic fins not fused into a disc (vs. fused). One species is introduced to eastern Europe and is spreading to the west. *Micropercops swinhonis* is sometimes reported to have been introduced from East Asia to eastern Europe. We did not find evidence that it has established. It is distinguished from *P. glenii* by a yellow to orange lower half of body and silvery bars on dark background.

Further reading. Hoese & Gill, 1993 (systematics); Kottelat & Freyhof, 2007b (nomenclature).

Perccottus glenii

Common name. Amur sleeper.

Diagnosis. Only species of family in Europe. Distinguished from all other European freshwater fishes by: ❍ two dorsals, first with 6–8 simple rays, second with 2–3 simple and 8–12 branched rays / ❍ first dorsal without spines / ❍ no barbels / ❍ pelvics not fused into a disc / ❍ no lateral line canals / ❍ during spawning period, males develop a hump on nape and become black with bright green spots on body and unpaired fins. Size up to 250 mm SL.

Distribution. Pacific basin of East Asia from Tugur drainage (Sea of Okhotsk) to northeastern Korea. Introduced in 1916 in St. Petersburg as an ornamental fish, now widely spread around and in Gulf of Finland. In Baltic basin, in Kaliningrad and widely spread in Vistula drainage in Poland and Ukraine. In 1950, released by aquarium hobbyists into lakes near Moscow (upper Volga drainage). Now very abundant throughout upper and middle Volga (upriver to Kuibushev Reservoir) and Kama. Also introduced and now abundant in upper Dniestr drainage (Ukraine) and locally established in Dniepr and Don drainages. In 1960s, introduced to Kazakhstan, Uzbekistan, Turkmenia and Lake Baikal mixed with Chinese carps. Spreading and abundant in northern Russia, Belarus and Ukraine. Local records from Slovakia (Danube). Already abundant in Tisza drainage (Hungary). Reported presence in Po drainage (Italy) not confirmed. Spreads actively via navigation canals and introduced with stocked fish.

Perccottus glenii; upper Dniestr drainage, Ukraine; nuptial male, ~50 mm SL.

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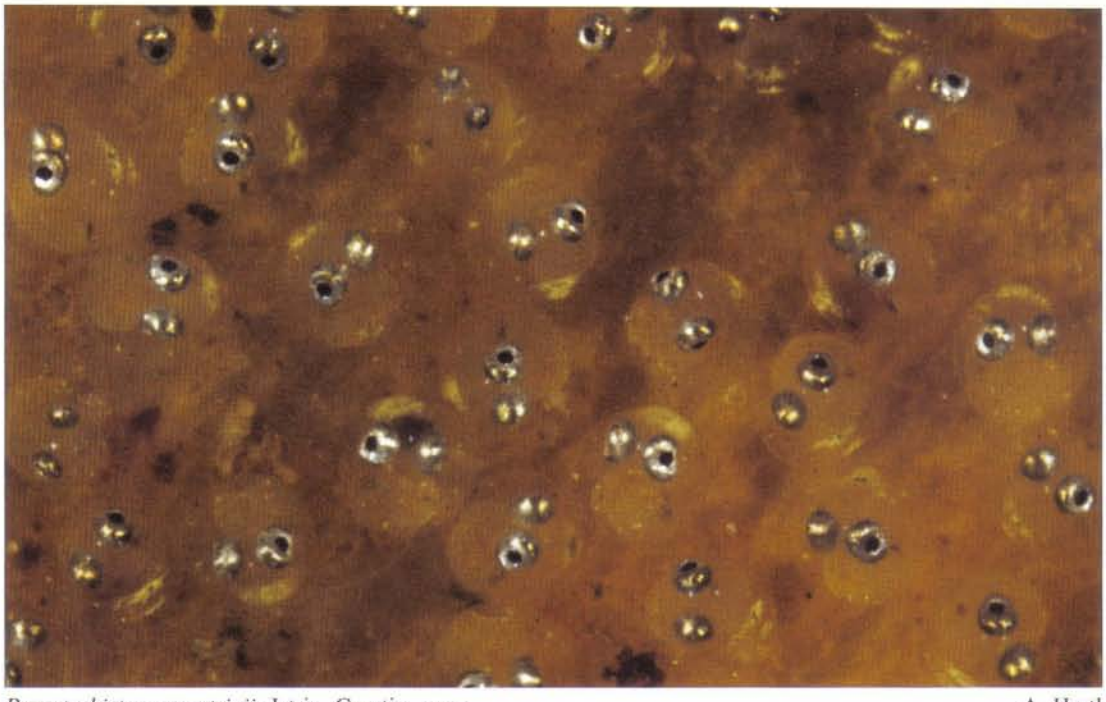
Perccottus glenii; upper Volga drainage, Russia; female, ~70 mm SL.

Habitat. Lentic waters, lakes, ponds, backwaters, and marshes with dense underwater vegetation; avoids river stretches with fast and even slow current.

Biology. Spawns for the first time at 1–3 years and about 60 mm SL. Spawns several portions of eggs in May – July at 15–20°C. Eggs elongated (3.8 × 1.3 mm), with sticky filaments, usually deposited in one row close to water surface on underwater structures (roots, leaves, etc.). Males guard eggs and larvae. Larvae are pelagic. Tolerates low oxygen concentrations and able to survive in dried out or completely frozen water bodies by digging itself into mud where it hibernates. Predatory, feeding on a wide variety of invertebrates, tadpoles and fish.

Conservation status. Alien. A voracious predatory fish constituting a most serious threat to aquatic fauna wherever it occurs. In small water bodies, known to extirpate almost all other fish species and amphibian larvae.

Further reading. Berg, 1949: 1056 (taxonomy); Diripasko, 1996 (invasion); Dimitriev, 1971 (invasion); Harka & Farkas, 1998 (invasion); Kautmann, 1999 (invasion).



Pomatoshistus canestrinii; Istria, Croatia; eggs. A. Hartl

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Family Gobiidae

Gobies

Very large family of about 2000 mostly marine species, distributed worldwide, most diverse in tropical coastal waters. Many species inhabit marine and brackish waters and a few are found in pure freshwater. In European waters, freshwater gobies are most diverse in the Mediterranean, Black and Caspian basins. Gobies are generally small benthic fishes. At 25 mm SL, *Economidichthys trichonis* is the smallest European freshwater fish. Gobies are distinguished from all other European freshwater fishes by having the pelvics fused to form a suction organ with an anterior transverse membrane. They also have two dorsals and have the pelvics located beneath the base of the pectoral. The taxonomy of all groups of European freshwater gobies is far from resolved. *Neogobius* is divided into several genera by some authors because of hypothesised relationships with some *Mesogobius* and *Proterorhinus*. Molecular data support the view that some species included in *Padogobius*, *Knipowitschia* and *Pomatoschistus* are not closely related to their congeners and several changes in generic nomenclature should be expected.

In Gobiidae, the count of scales in midlateral series usually starts at the upper extremity of the base of the pectoral.

Gobius cobitis, *G. niger*, *Zosterisessor ophiocephalus* and some *Pomatoschistus* species are occasionally recorded as occurring in freshwater, but we are not aware of documented records of their actual occurrence in European freshwaters.

Several species are presently expanding their range upriver in the Black and Caspian Sea basins. In some (as *Proterorhinus semilunaris*) this seems to be a slow process resulting from active upriver migration; in others (as *Neogobius kessleri*, *N. melanostomus* and *N. gymnotrachelus*) it is a rapid invasion with the species suddenly appearing far upstream of their former range. The recent discovery of *N. kessleri* in the upper Danube (Germany) and of the same species, *N. melanostomus* and *N. gymnotrachelus* in Austria is probably the result of passive introduction (adults or eggs transported by shipping). Although such accidental transports may have been going on for hundreds of years, the invasion by gobies and many Ponto-Caspian crustaceans has significantly increased in the last 20 years. Invasions of gobies and invertebrates are reported to be facilitated by the construction of dams, river pollution with salt and by the canalization of main rivers.

Further reading. Miller, 2003, 2004.

Pomatoschistus canestrinii; Istria, Croatia; spawning. A. Hartl

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Cephalic pores and papillae in Gobiidae

The canal, pores and sensory papillae of the lateral line system provide important diagnostic characters to distinguish goby genera and species. Figure 89 shows the terminology and notation system used. Canals are stippled and pores indicated by Greek letters. There is no lateral line canal on the flank, and the canals may be variously developed on the head. In the species with the most developed canals, there is an anterior oculoscapular canal (from pores σ to ρ), a posterior oculoscapular canal (from pores ρ^1 to ρ^2) and a preopercular canal (from pores γ to ε). Parts or all of these canals may be missing or interrupted; and posterior and anterior oculoscapular canals may be continuous or not. The anterior oculoscapular canals of both sides of the head may be separate or fused in the interorbital area. The anterior oculoscapular canal itself may be divided into a circumorbital and postorbital segment. The papillae are organised either in vertical rows (numbered in Fig. 89) or longitudinal rows (lettered in Fig. 89).

A dissecting microscope is necessary to examine the pores and papillae. They are best viewed using oblique light. Sometimes they may be hidden by mucus. Some authors have sought to highlight the canals by injection of chromic acid, ferric tannate or potassium permanganate, but all these methods damage the specimens. Air pulsed by a small aquarium pump through an injection needle is a technique now used by goby specialists. Goby identification, however, continues to be difficult even for specialists.

Further reading. Sanzo, 1911; Miller, in Whitehead et al., 1986.

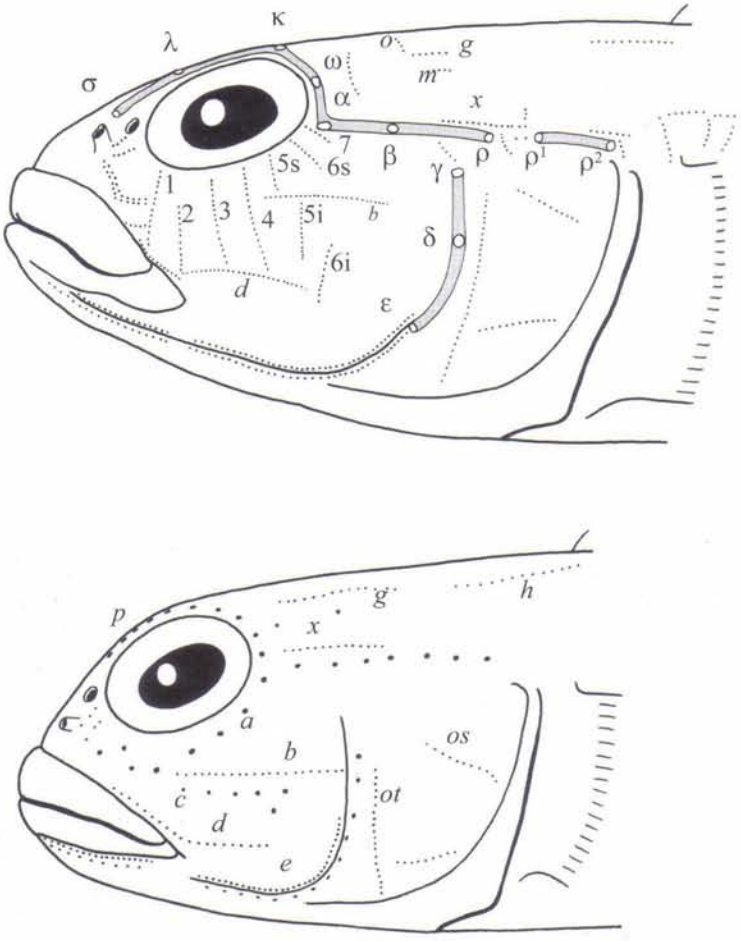

Figure 89 Cephalic lateral line system in Gobiidae (after Miller, in Whitehead et al., 1986).

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Key to genera of Gobiidae entering European freshwaters

1a – Anterior part of body (until second dorsal and anal origins) very broad and flattened; one small barbel on chin.
..... *Benthophilus*

1b – Anterior part of body not very broad and flattened; no barbel on chin.
..... 2

2a – Cephalic lateral line canals absent.
..... 3

2b – Cephalic lateral line canals present (Fig. 89).
..... 7

3a – Peri-anal organ present, surrounding anus and extending anteriorly along midventral line of scaleless abdomen (Fig. 90).
..... *Economidichthys*

3b – Peri-anal organ absent.
..... 4

4a – Body completely covered with overlapping scales.
..... *Padogobius* (in part)

4b – Body naked or at least predorsal region and back naked, or body covered with small, non-overlapping scales, spines or bony plates.
..... 5

5a – 7–8½ branched rays in second dorsal; males with 4–12 narrow bars or spots on flank.
..... *Knipowitschia* (in part)

5b – 11–13½ branched rays in second dorsal; 2–3 wide dark bars on flank in both sexes.
..... 6

6a – Caudal-peduncle 1.0–1.5 times longer than deep; body with small, non-overlapping scales with long lateral ctenii in juveniles (Fig. 91), adults naked; ventral part of second bar wider than its middle part.
..... *Benthophiloides*

6b – Caudal-peduncle about 3 times longer than deep; head and body naked in juveniles and adults; ventral part of second bar narrower than its middle part.
..... *Caspiosoma*

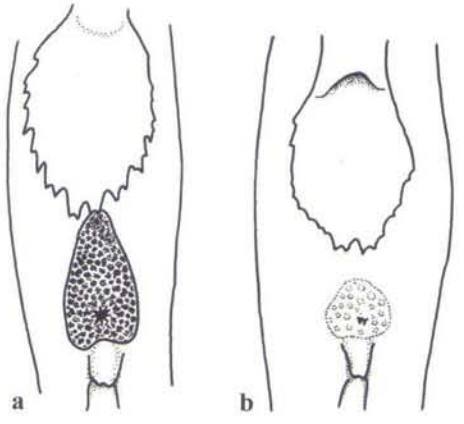

Figure 90 Perianal organ of *Economidichthys* species: **a,** *E. pygmaeus*; **b,** *E. trichonis* (after Economidis & Miller, 1990).

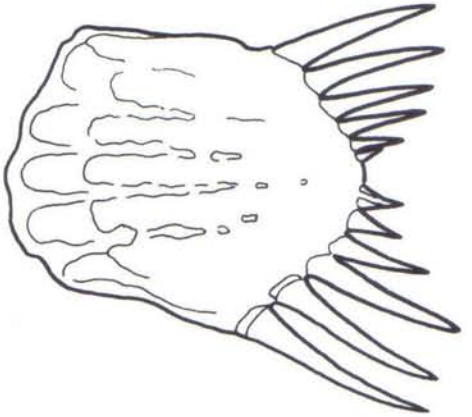

Figure 91 Scales of juvenile *Benthophiloides brauneri* (after Beling & Iljin, 1927).

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Figure 92 Anterior oculoscapular canal ending: **a,** on snout (pore σ) in *Pomatoschistus* species; **b,** in front of middle of eye (pore λ) in some *Knipowitschia* species; **c,** behind middle of eye (pores κ) in some *Knipowitschia* species.

7a – 5–13½ branched rays in second dorsal. 8

7b – 14–20½ branched rays in second dorsal. 10

8a – Anterior oculoscapular canal ending anteriorly in interorbital area (pores λ-κ; Fig. 92b-c). ..... *Knipowitschia* (in part)

8b – Anterior oculoscapular canal extending onto snout (pore σ; Fig. 92a). 9

9a – Anal origin below simple or first branched ray of second dorsal. ..... *Pomatoschistus*

9b – Anal origin below 3–5th branched ray of second dorsal. ..... *Padogobius* (in part)

10a – Anterior naris at end of a tube projecting forward beyond lip; 36–48 total scales in midlateral series. ..... *Proterorhinus*

10b – Anterior naris not projecting forward beyond lip; 49–85 total scales in midlateral series. 11

11a – 7 vertical rows of papillae in suborbital area (Fig. 93a); 49–74 total scales in midlateral series; nape covered with scales, if nape naked then 54–65 scales in midlateral series. ..... *Neogobius*

11b – 8–10 vertical rows of papillae in suborbital area (Fig. 93b); 72–85 total scales in midlateral series; nape naked. ..... *Mesogobius*

Benthophiloides brauneri

Common name. Beardless tadpole goby.

Diagnosis. Distinguished from other species of Gobiidae in Europe by: ● in juveniles, body with small, non-overlapping scales with long lateral ctenii (Fig. 91) / ○ body naked in adults / ○ no chin barbel / ○ 𝓘 broad dark bars around body, one below first dorsal and one under posterior half of second dorsal, ventral part of second bar wider than its middle part / ○ cephalic lateral line canals absent / ○ 11–13½ branched rays in second dorsal / ○ caudal-peduncle 1.0–1.5 times longer than deep. Size up to 72 mm SL.

Distribution. Azov and Black Seas. A dubious record from Caspian Sea.

Habitat. Very rarely observed. Estuaries, coastal lakes and lower part of rivers, at depths up to 15 m, in still, fresh and brackish water.

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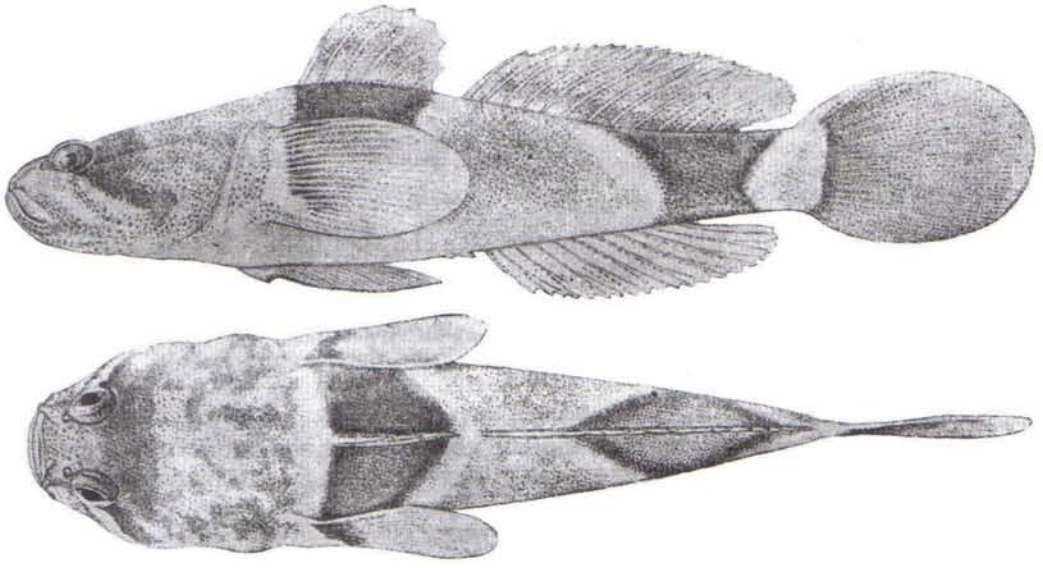
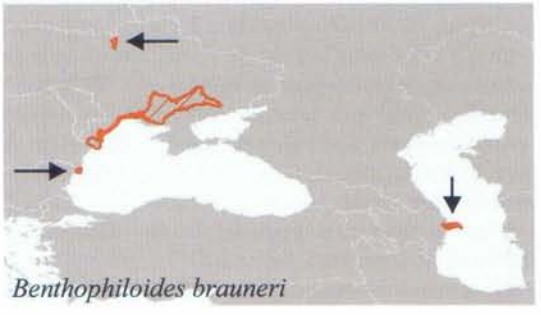


Benthophiloides brauneri; Dniepr, Ukraine; 31 mm SL. (from Belling & Iljin, 1927)

Biology. Lives only one year. Spawns in July – August, possibly only a small batch of about 20–30 eggs. Feeds on small crustaceans, gastropods and insect larvae.
Conservation status. DD.
Further reading. Pinchuk & Miller, in Miller, 2004: 153 (description, biology).

Benthophilus

The body of *Benthophilus* species is covered by bony projections of various shapes and sizes, called *tubercles* and *granules*. ***Tubercles*** are spherical, spiny, thorny or stellate (a thorn with multiple prongs) bony scutes on head and body whose size is at least equal to about the pupil diameter; they are easily seen with the naked eye and usually organised into longitudinal rows: a dorsal row, a ventral row and 1 or 2 lateral rows (upper lateral and lower lateral). Tubercle counts in each row do not include those on the head and the caudal fin (if present); we list here only the usual values for each count and slightly higher or lower values should be expected. When tubercles are developed, there is one (two in *B. leobergius*) between the anterior margins of the eyes and usually one also behind the eyes. ***Granules*** are small bony projections on the head and body, much smaller than eye diameter. In mature males, granules and tubercles are often reduced and the body may be completely naked. Most *Benthophilus* species have three dark blotches on back and flank, the anteri-



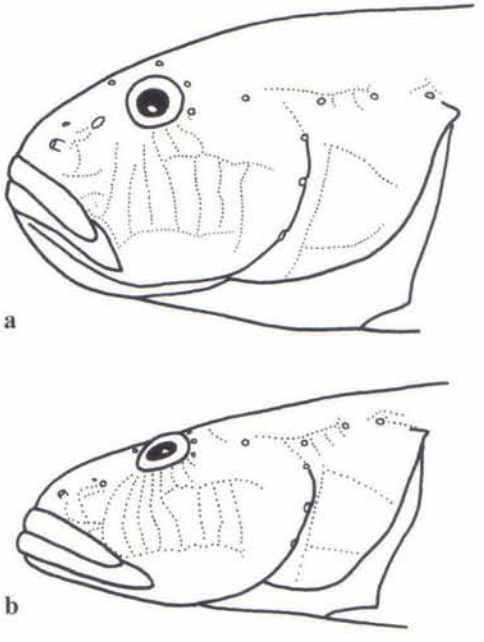


Figure 93 Rows of suborbital transverse papillae in: **a,** *Neogobius syrman*; **b,** *Mesogobius batrachocephalus* (after Miller, in Whitehead et al., 1986).

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or one in front of or under first dorsal; the second one at end of base of second dorsal; and third one at caudal base.

There are some 20 species of *Benthophilus*. They are known from the Caspian, Azov and Black Seas. Some are strictly marine (in littoral zone or in deep waters), others inhabit the estuaries and freshwaters. Only the species recorded from freshwaters are included here, but some of the estuarine species may be expected occasionally to enter freshwaters, for example *B. abdurahmanovi*, *B. baeri* and *B. casachicus*.

Further reading. Boldyrev & Bogutskaya, 2004, 2007 (systematics).

Key to species of *Benthophilus* entering European freshwaters

1a – Tubercles absent, body covered with densely-set thorny bony granules of different size, not arranged in rows. ..... *B. granulosus*

1b – Tubercles present, arranged in 3–4 longitudinal rows on each side of body; small bony granules between rows of tubercles present or absent. 2

2a – 13–15 very large, high, pointed tubercles in dorsal row; 11–12 tubercles in ventral row; first dorsal usually reduced to a single spine. ..... *B. baeri*

2b – 24–30 tubercles in dorsal row; 20–25 tubercles in ventral row; 3–4 rays in first dorsal. 3

3a – No or indistinct dark brown saddles or blotches on back. 4

3b – Three distinct large dark irregularly shaped blotches or saddles along midline of back and flank. 6

4a – Tubercles on head and body conspicuously larger than granules. ..... *B. macrocephalus*

4b – Tubercles and granules on head of almost equal size, only 1 or 2 distinct tubercles on nape. 5

5a – Mouth width more than 4.5 times eye diameter; usually 9½ branched rays in second dorsal and 8½ branched rays in anal. ..... *B. abdurahmanovi*

5b – Mouth width less than 4.5 times eye diameters; usually 10½ branched rays in second dorsal and 9½ branched rays in anal. ..... *B. magistri*

6a – Groove between eyes along midline of head; granules on head behind eyes large (some of them almost of same size as nearby tubercles). ..... *B. casachicus*

6b – No groove between eyes; granules on head tiny. 7

7a – Two tubercles between eyes. ..... *B. leobergius*

7b – A single tubercle between eyes. 8

8a – Origin of second dorsal behind origin of anal. 9

8b – Origin of second dorsal in front of origin of anal. 10

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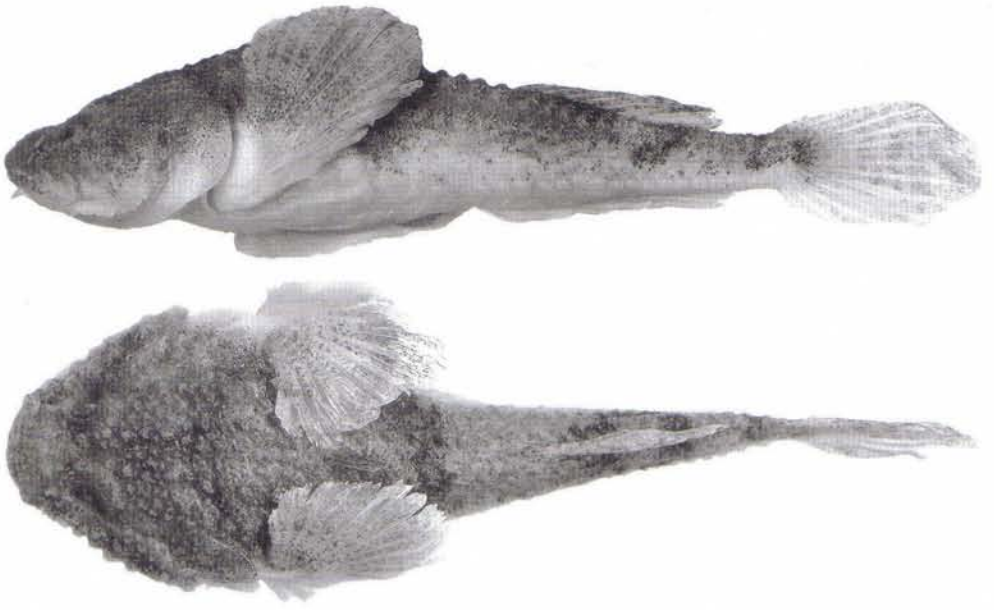

Benthophilus durrelli; Don, Russia; 43 mm SL. A. Naseka

9a – Granules present between dorsal and upper lateral rows of tubercles on whole body; sparse granules on abdomen in front of pelvics; transverse rows of neuromasts on flank usually 20–22.
..... *B. mahmudbejovi*

9b – Granules sparse on flank and absent on caudal peduncle; no granules on abdomen; transverse rows of neuromasts on flank usually 16–19.
..... *B. durrelli*

10a – Head width 77–92 % of its length; blotch around base of first dorsal not reaching origin of second dorsal; a dark spot in front of second dorsal fin usually present.
..... *B. nudus*

10b – Head width 94–104 % of its length; blotch around base of first dorsal usually reaching origin of second dorsal; no additional spot in front of second dorsal.
..... *B. stellatus*

Benthophilus durrelli

Common name. Don tadpole-goby.

Diagnosis. Distinguished from other *Benthophilus* entering freshwater by: ❍ a single tubercle between eyes / ❍ granules few, sparse on flank, absent on caudal peduncle / ❍ tubercles small, of same size on head and body / ❍ 26–29 tubercles in dorsal row, 20–24 in ventral row, 19–27 in upper lateral row (conspicuously smaller on caudal peduncle), 10 in lower lateral row (tiny) / ❍ first dorsal with 3–4 spines / ❍ chin barbel slightly compressed, with thick base, longer than half eye diameter / ❍ origin of second dorsal behind origin of anal / ❍ 16–19 transverse rows of neuromasts on flank / ❍ a small dark spot in front of second dorsal / ❍ flank with dark blotches and irregular dots / ❍ blotch around base of first dorsal not reaching origin of second dorsal. Size up to 66 mm SL.

Distribution. Sea of Azov: Gulf of Taganrog; lower Kuban and Don drainages; in Don upstream to Tsimlyansk Reservoir. Introduced (mixed with mysids) in Kuibyshev reservoir on Volga, from where it spread in Volga, from Gorgy to Volgograd reservoirs.

Habitat. Fresh and brackish waters. In coastal areas of Sea of Azov, but mostly at river mouths (saline water, up to 3 ‰), lower reaches of rivers, and reservoirs. Prefers silty sand with mollusc shells.

Biology. Lives about 1 year. Spawns in May – August. Females probably lay eggs in 2–3 por-

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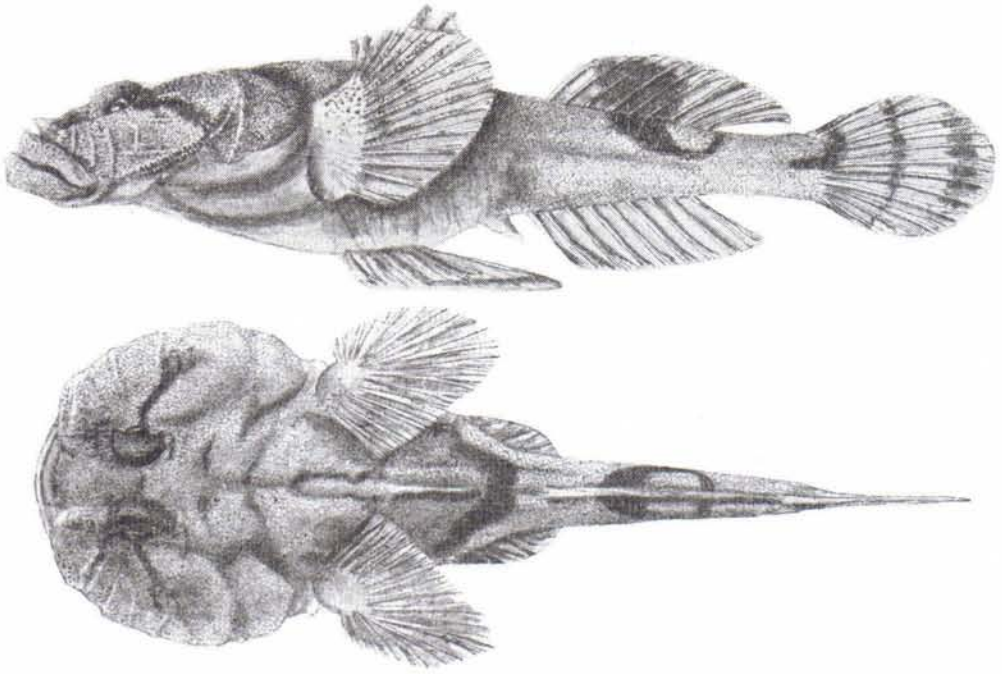


Benthophilus granulosus; Caspian Sea, Azerbaidjan; 47 mm SL. (from Berg, 1932, 1949)

tions inside or under a mollusc shell. Adults die soon after spawning. Feeds mainly on insect larvae and small molluscs.

Conservation status. LC.

Remarks. Earlier considered conspecific with *B. stellatus*.

Further reading. Evlanov et al., 1998 (invasion, biology, as *B. stellatus*); Boldyrev & Bogutskaya, 2004: 130, 2007: 53 (description; distribution).

Benthophilus granulosus

Common name. Granular tadpole-goby.

Diagnosis. Distinguished from other *Benthophilus* entering freshwater by: ● no tubercles on head and body / ○ body covered by numerous, densely-set thorny granules / ● chin barbel with swollen base, thin and elongated distally / ○ three dark blotches along midline of back and flank / ○ dark dots on head and back, sometimes on dorsal, pectoral and caudal. Size up to 56 mm SL.

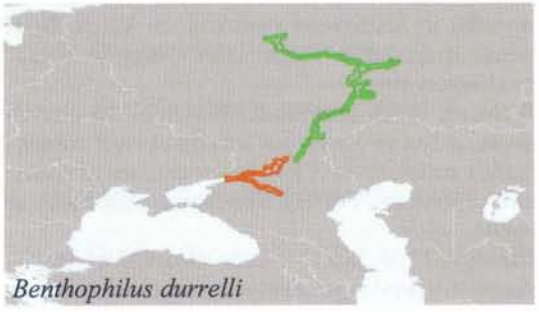
Distribution. Caspian Sea. Common along northern and eastern coasts, at river mouths, especially Ural and Volga, lower reaches of Volga up to Astrakhan.

Habitat. Both fresh and marine waters; prefers brackish and slightly saline zones in deltas and estuaries. In summer inhabits shallow coastal waters (0.5–20 m) and shallow channels of deltas, moves to deeper areas (down to 60–70 m) in winter.

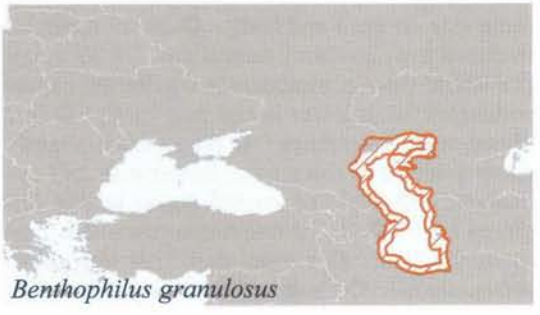
Biology. Spawns after first winter. In northern Caspian Sea and Volga delta, spawns in April – July in shallow water. Feeds mostly on molluscs and crustaceans.

Conservation status. LC.

Further reading. Berg, 1949: 1119 (description); Ragimov, 1981: 228 (distribution), 1985b: 920 (morphology); Boldyrev & Bogutskaya, 2007: 49 (description).



Benthophilus durrelli



Benthophilus granulosus

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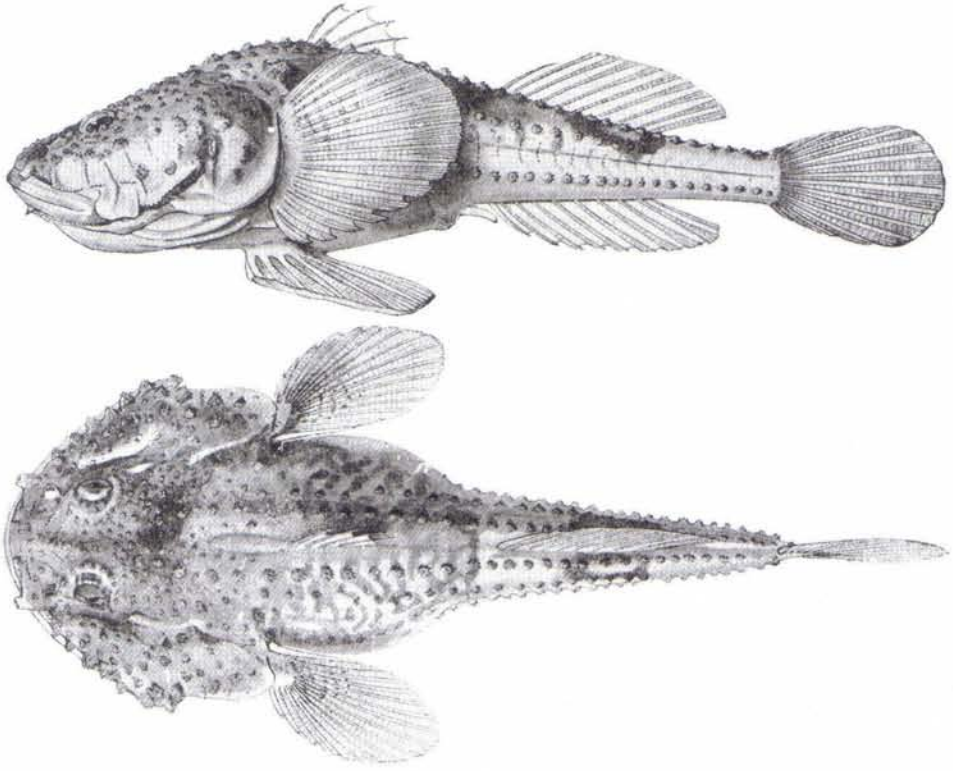


Benthophilus leobergius; Caspian Sea; 103 mm SL. (from Berg, 1932)

Benthophilus leobergius

Common name. Caspian stellate tadpole-goby.

Diagnosis. Distinguished from other *Benthophilus* entering freshwater by: ● two tubercles between eyes / ● upper jaw conspicuously projecting / ○ 27–30 tubercles in dorsal row, 22–25 in ventral row, 15–24 in upper lateral row, lower lateral row usually absent / ● granules few, sparse, on head and back in front of first dorsal, with a few larger granules between upper lateral and dorsal rows of tubercles / ○ chin barbel slightly compressed, length about half of eye diameter / ○ first dorsal with 3–4 spines / ○ flank with dark blotches and irregular dots. Size up to 98 mm SL.

Distribution. Northern, western and southern parts of Caspian Sea. Lower reaches of Volga up to Astrakhan.

Habitat. Fresh, brackish, rarely marine waters, prefers salinity below 9 ‰. In still or slowly flowing water over mud bottom. At depths around 0.5–10 m in summer, moves to deeper places in winter.

Biology. Lives about 1 year. Spawns in April – October. Females lay eggs in two, sometimes more, portions. Females die shortly after last release of eggs, males 3–4 weeks later. Males probably guard a clutch of eggs until hatching. Feeds on benthic invertebrates, mainly molluscs.

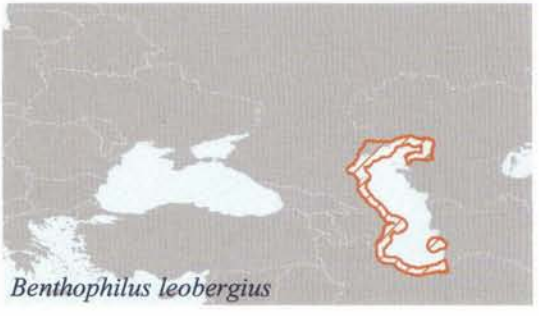
Conservation status. LC.

Further reading. Pinchuk et al., in Miller, 2004: 207 (description, biology); Boldyrev & Bogutskaya, 2007: 60 (description).

Benthophilus macrocephalus

Common name. Caspian tadpole-goby.

Diagnosis. Distinguished from other *Benthophilus* entering freshwater by: ● tubercles conspicuously larger than granules, 24-26 of equal size in dorsal row, 21–22 in ventral row, up to 20 in upper lateral row, lower ventral row usually absent / ○ granules numerous, densely-set, appearing as small spines, covering most of top of head, back, flanks and caudal peduncle / ● semicircular patch of granules along upper eye margin / ● chin barbel thick, conical / ○ body plain grey / ○ first dorsal



Benthophilus leobergius

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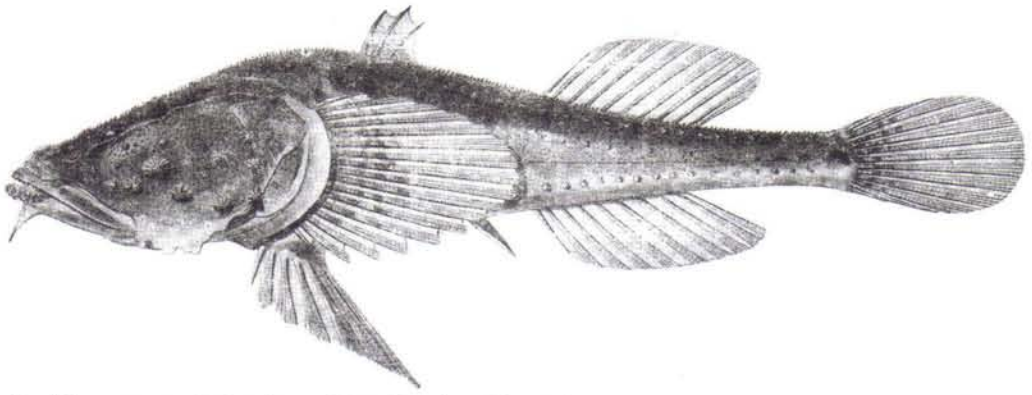


Benthophilus macrocephalus; lower Volga, Russia; 110 mm SL. (from Berg, 1932)

Benthophilus macrocephalus; lower Volga, Russia; 110 mm SL. (from Berg, 1932)

with 3–4 spines. Size up to 97 mm SL.

Distribution. Caspian Sea, along most costs; Volga up to Astrakhan.

Habitat. Shallow coastal waters and estuaries, usually at 0.5–10 m depth, over mud bottom; lower reaches of rivers. Widely distributed but rare. During warm seasons prefers coastal waters down to 10 m. In northern Caspian Sea, moves to deeper areas (20–25 m) in winter.

Biology. Lives about 1 year. Forms schools during spawning season (April – July) in coastal shallows over hard mud bottom with mollusc shells. Females lay eggs in at least two portions into empty shells. Feeds mostly on molluscs and fish (small gobies), also worms and crustaceans.

Conservation status. LC.

Further reading. Vasilieva, 1983: 545 (taxonomy); Ragimov, 1985a: 243 (distribution, biology); Pinchuk et al., in Miller, 2004: 225 (description, biology); Boldyrev & Bogutskaya, 2007: 67 (description).

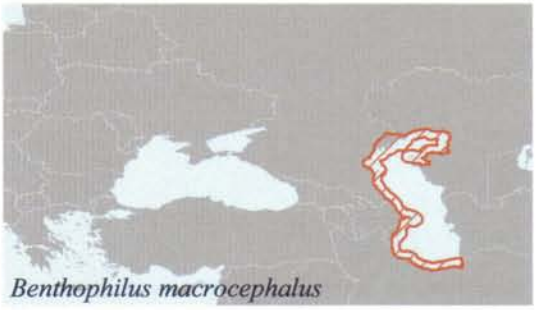
Benthophilus magistri

Common name. Azov tadpole-goby.

Diagnosis. Distinguished from other *Benthophilus* entering freshwater by: ✪ second dorsal with 9–11½ branched rays / ✪ anal with 8–10½ branched rays / ✪ tubercles and granules on head of almost equal size / ✪ no tubercle on dorsal midline of head behind eye / ✪ whole body except abdominal area covered by numerous, densely-set granules / ✪ 28–30 tubercles in dorsal row, 23–25 in ventral row, more than 20 in upper and lower lateral rows (small, especially in caudal area) / ✪ size of tubercles of dorsal row increasing from head to base of first dorsal / ✪ no dark blotches on body. Size up to 71 mm SL.

Distribution. Sea of Azov. Common along northern and eastern coasts, in river mouths, especially Gulf of Taganrog.

Habitat. Fresh and slightly brackish waters with



Benthophilus macrocephalus

Benthophilus magistri

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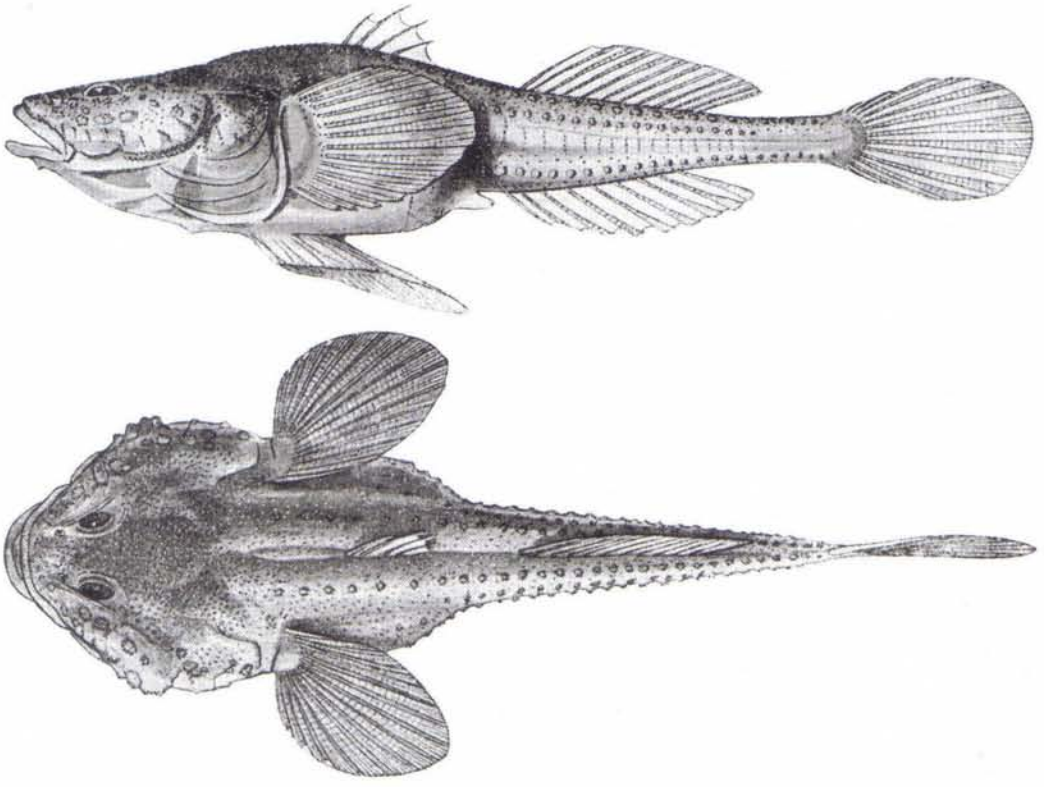

Benthophilus magistri; Sea of Azov, Ukraine; 50 mm SL. (from Berg, 1932)

salinity below 11‰, usually over mud bottom.
Biology. Lives about 1 year. Females probably lay eggs in 2–3 portions within or under a mollusc shell. Adults die soon after spawning. Feeds mainly on molluscs, crustaceans and chironomid larvae.
Conservation status. LC.
Further reading. Iljin, 1927: 131 (description); Smirnov, 1986: 181 (morphology); Pinchuk et al., in Miller, 2004: 235 (description); Boldyrev & Bogutskaya, 2007: 58 (description).

Benthophilus mahmudbejovi

Common name. Small-spine tadpole-goby.
Diagnosis. Distinguished from other *Benthophilus* entering freshwater by: ● head strongly depressed / ○ a single tubercle between eyes / ○ granules numerous, densely-set, covering whole body except abdominal area / ○ tubercles small, especially on head / ○ 26–29 tubercles in dorsal row, 21–24 in ventral row, about 20 in upper lateral row (conspicuously smaller on caudal peduncle), 10 in lower lateral row (tiny) / ○ first dorsal usually with 4 spines / ○ chin barbel slightly compressed, with thick base, longer than half eye diameter / ○ origin of second dorsal behind origin of anal / ○ usually 20–22 transverse rows of neuromasts on flank / ○ often a dark spot in front of second dorsal / ○ flank with dark blotches and irregular dots. Size up to 55 mm SL.
Distribution. Eastern coast of Caspian Sea and Volga delta, Volga up to Volgograd.
Habitat. Fresh and brackish waters, salinity up to 13 ‰. Down to 50 m, mature adults at 1–11 m.
Biology. Lives about 1 year. Spawns in May – August in northern Caspian, in April – November in eastern Caspian. Some individuals may spawn for the first time at 6–7 months. Females probably lay eggs in 3 portions. Females die after spawning, males probably 3–4 weeks later.
Conservation status. LC.
Further reading. Ragimov, 1976: 796 (description), 1981: 228 (distribution); Pinchuk & Miller,

Benthophilus mahmudbejovi

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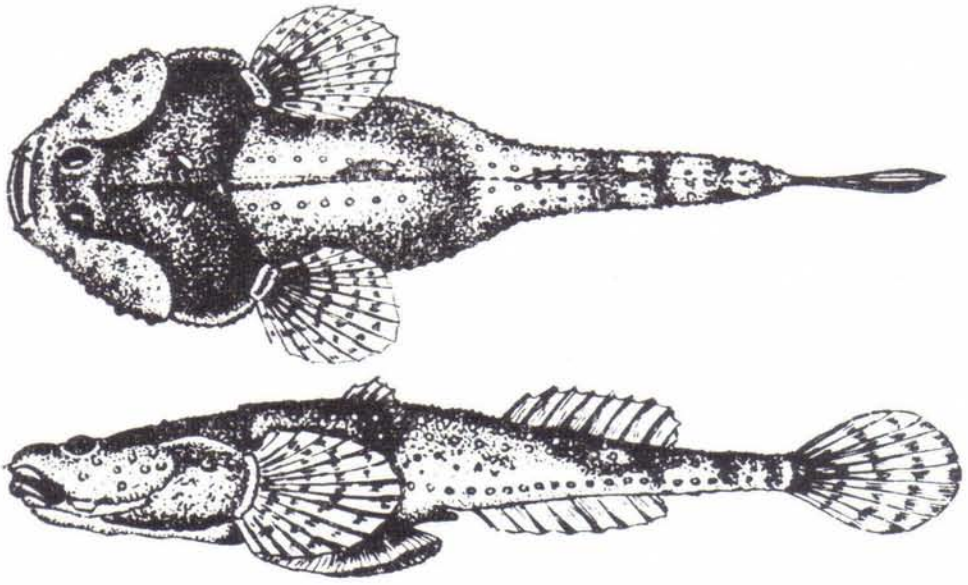

Benthophilus mahmudbejovi; Caspian Sea, Kazakhstan; 40 mm SL. (from Ragimov, 1976)

Benthophilus nudus; Lake Sinoe, Romania; ~100 mm SL.

Benthophilus nudus; Lake Sinoe, Romania; ~100 mm SL. Note chin barbel.

in Miller, 2004: 241 (description, biology); Boldyrev & Bogutskaya, 2007: 51 (description).

Benthophilus nudus

Common name. Black Sea tadpole-goby.

Diagnosis. Distinguished from other *Benthophilus* entering freshwater by: ○ a single tubercle between eyes / ○ granules numerous, densely-set on head and flanks, present between dorsal and upper lateral rows of tubercles on caudal peduncle / ○ head width 77–92 % HL / ○ 26–29 tubercles in dorsal row, 22–25 in ventral row, over 20 in upper lateral row (not markedly smaller on caudal peduncle), up to 10 in lower lateral row / ○ first dorsal usually with 3 spines / ○ chin barbel slightly compressed, thick, length about half eye diameter / ○ origin of second dorsal in front of origin of anal / ○ 19–23 transverse rows of neuromasts on flank / ○ dark spot in front of second dorsal / ○ flank with dark blotches and irregular dots / ○ blotch around base of first dorsal not reaching origin of second dorsal. Size up to 115 mm SL.

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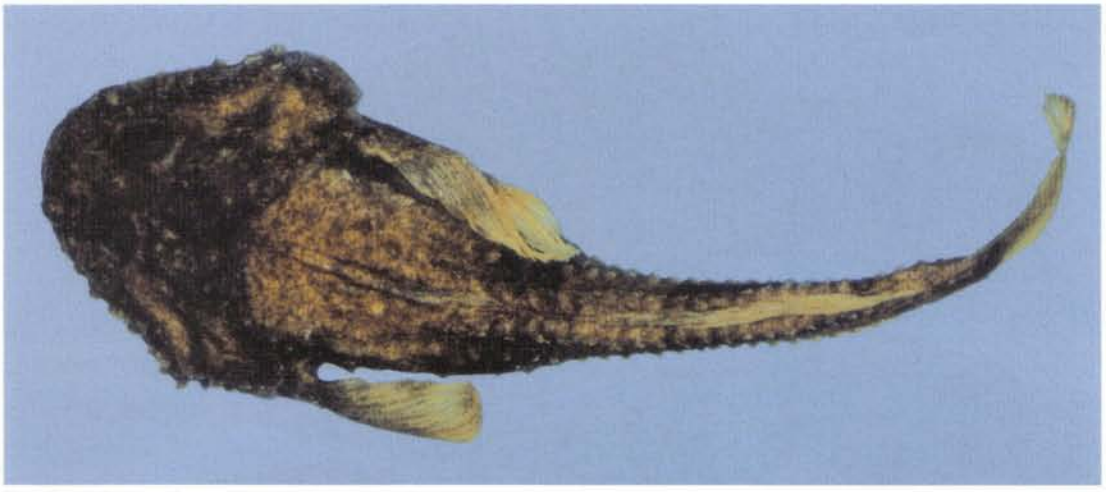
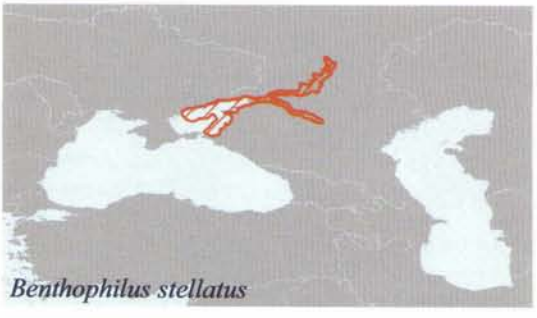


Benthophilus stellatus; Sea of Azov, Ukraine; 72 mm SL. A. Naseka

Distribution. Black Sea basin; coastal lakes of northwestern Black Sea. Native range not clear. In Danube upstream to Iron Gate (Romania), in Dniestr to Bendery, in South Bug to Gard rapids. Invasive in Dniepr after damming in late 1940s, now up to Kiev.
Habitat. Fresh and slightly brackish waters. Prefers lowland rivers, deltas and coastal lakes. In rivers, usually abundant in main stream. Usually on silty sand with mollusc shells.
Biology. Lives about 1 year. Spawns in May – August. Females probably lay eggs in 2–3 portions inside or under a mollusc shell. Adults die soon after spawning. Feeds mainly on chironomid larvae, amphipods and molluscs.
Conservation status. LC.
Remarks. Earlier considered conspecific with *B. stellatus*.
Further reading. Bănărescu, 1964: 861 (description, biology; as *B. stellatus*); Boldyrev & Bogutskaya, 2004: 132 (description; distribution); Boldyrev & Bogutskaya, 2007: 65 (description).

Benthophilus stellatus

Common name. Stellate tadpole-goby.
Diagnosis. Distinguished from other *Benthophilus* entering freshwater by: ○ a single tubercle between eyes / ○ granules not numerous, sparse on flank, backward only to below second dorsal base, rarely present between upper lateral and dorsal rows of tubercles / ○ head width 94–104 % HL / ○ 27–30 tubercles in dorsal row, 22–25 in ventral row, 10–16 in upper lateral row (slightly smaller posteriorly), lower lateral row with few tiny tubercles or missing / ○ first dorsal usually with 3 spines / ○ chin barbel slightly compressed, thick, length about equal to eye diameter / ○ origin of second dorsal in front of origin of anal / ○ 18–23 transverse rows of neuromasts on flank / ○ no spot in front of second dorsal / ○ flank with dark blotches and irregular spots / ● blotch around base of first dorsal usually reaching origin of second dorsal. Size up to 117 mm SL.
Distribution. Sea of Azov basin; Don (upstream to Tsimlyanskoje reservoir), Severski Donets and Manych drainages. Historical record in Don as far up as Voronezh needs confirmation.
Habitat. Shallow coastal lagoons and lowland rivers, in fresh and brackish water with salinity below 12 ‰. In rivers, prefers mainstream, more than 3 m deep and with mud bottom. In Sea of Azov over sand, avoiding silted areas.
Biology. Spawns after first winter, in May – June. Females die shortly after spawning, males some weeks later. Feeds mainly on molluscs, insects and crustaceans.
Conservation status. LC.
Further reading. Pinchuk & Miller, in Miller, 2004: 241 (description, biology, Sea of Azov basin); Boldyrev & Bogutskaya, 2007: 63 (description).



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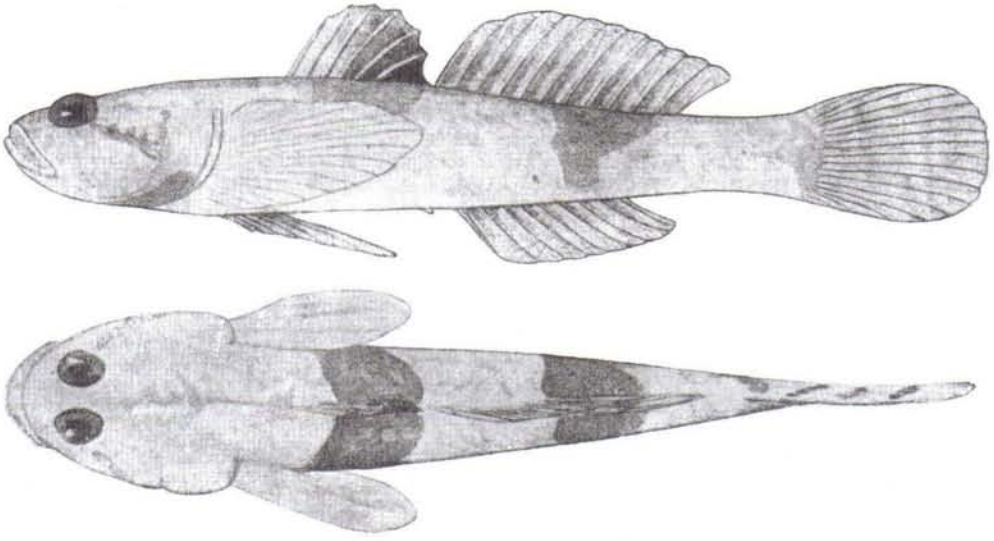


Caspiosoma caspium; mouth of Don, Russia; ~40 mm SL. (from Beling & Iljin, 1927)

Caspiosoma caspium

Common name. Caspian goby.

Diagnosis. Distinguished from other species of Gobiidae in European freshwaters by: O body slightly laterally compressed, anterior part neither significantly wider nor flatter than caudal peduncle / O head length 25–30 % SL / O body naked (no scales, no granules, no tubercles) / O 2–3 wide dark bars on body / O cephalic lateral line canals absent / O 11–13½ branched rays in second dorsal / O caudal-peduncle about 3 times longer than deep / O first dorsal with 5–7 spines / O posterior extremity of membranes of first dorsal reaching origin of second dorsal / O eye diameter about 20 % HL / O interorbital distance smaller than eye diameter / O ventral part of second bar narrower than its middle part. Size up to 50 mm SL.

Distribution. Lower reaches, deltas and limans of rivers draining to northern Black Sea (Dniestr, Dniepr), Sea of Azov (Don and Kuban deltas, mouth of smaller rivers) and Caspian Sea (delta and lower reaches of Volga).

Habitat. Fresh and slightly brackish water with salinity up to about 10 ‰; usually over mud bottom.

Biology. Probably lives only 1 year. Spawns in May – August, in shallow areas, at 0.5–0.8 m depth (also reported down to 20 m), with some current, hard sand, mud or clay bottom and with little vegetation. Spawns in empty mollusc shells. Probably spawns eggs (4.3 × 1.8 mm) in several portions. Males probably tend the nest. Feeds on benthic invertebrates, rotifers and algae.

Conservation status. LC. Very rarely observed.

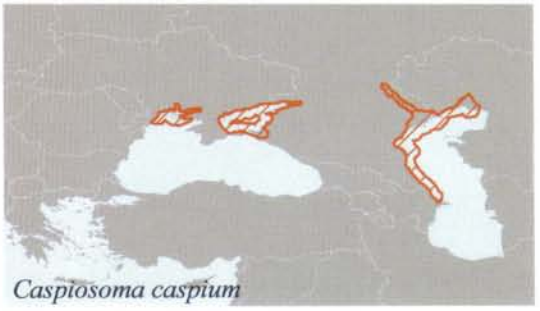
Further reading. Iljin, 1927: 129 (description); Berg, 1949: 1104 (diagnosis); Smirnov, 1986: 167 (morphology); Pinchuk et al., in Miller, 2004: 141 (biology).

Economidichthys pygmaeus

Common name. Western Greece goby.

Diagnosis. Distinguished from its only congener *E. trichonis* by: ● length of peri-anal organ (Fig. 90a) at least half of pelvic-disc length / ● caudal peduncle entirely covered by scales below end of dorsal base / ● body dark or with short transverse lateral blotches or bars. Size up to 47 mm SL.

Distribution. Greece: Epiros and Etolo-Akarna-



Caspiosoma caspium

Economidichthys pygmaeus

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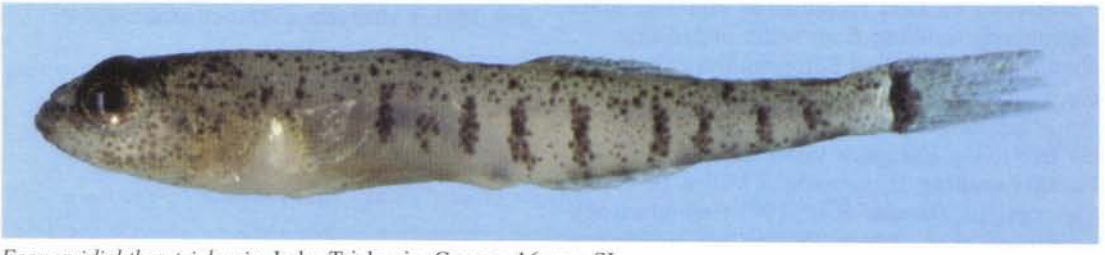
Economidichthys pygmaeus; Louros drainage, Greece; male, 32 mm SL.

Economidichthys pygmaeus; Louros drainage, Greece; female, 25 mm SL.



Economidichthys trichonis; Lake Trichonis, Greece; 16 mm SL.

nia, from Kalamas to Acheloos drainages; isolated springs on Lefkas Island.

Habitat. In streams and lakes: mainly in reed stands and among dense vegetation, less than 8 m depth.

Biology. Spawns after first winter, in February – May in Lake Trichonis, until late August on Lefkas island. Eggs (2.4 × 0.9 mm) are spawned in a cavity (usually inside standing, broken reeds); they are cleaned and guarded by the male. Up to 600 eggs are spawned by several females in a single nest. Individual females may spawn more than once during a season. Eggs hatch probably in one day, the larvae living on the bottom. Male and female die shortly after spawning. Feeds mainly on amphipods and copepods.

Conservation status. LC.

Remarks. The peri-anal organ has been hypothesised to secrete substances acting against egg infections. Despite the shared presence of the peri-anal organ, larval morphology does not suggest close affinities between the two species currently placed in *Economidichthys*.

Further reading. Bianco et al., 1987: 797 (description); Economidis & Miller, 1990: 134 (description); Daoulas et al., 1993 (reproduction); Economou et al., 1994a: 26 (larvae); Economou et al., in Miller, 2004: 443 (biology).

Economidichthys trichonis

Common name. Trichonis dwarf goby.

Diagnosis. Distinguished from its only congener *E. pygmaeus* by: ● length of peri-anal organ (Fig. 90b) less than half of pelvic-disc length / ● a single longitudinal row of scales on caudal peduncle below end of dorsal base / ● body whitish with vertical bars, translucent in life. Size up to 25 mm SL.

Distribution. Greece: Lakes Trichonis and Lysimachia.

Habitat. Near bottom in areas covered by aquatic vegetation, in reed stands, and in sheltered bays, down to 15 m.

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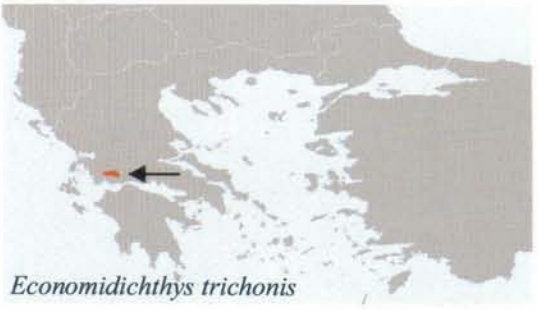

Economidichthys trichonis

Biology. Spawns after first winter, in February – May. Eggs (0.7 × 0.6 mm) are spawned in a cavity (usually inside standing, broken reeds); they are cleaned and guarded by the male. A single nest usually is occupied by up to 2000 eggs spawned by several females. Females may spawn at least twice during a season. Eggs hatch in about one day. Early larvae live in the surface layer, near shore. After yolk absorption, they live in deeper layers or near the bottom, and move upward at night. Maximum known age 21 months. Feeds mainly on cladocera and larvae of the mussel *Dreissena polymorpha* during its spawning season.
Conservation status. EN B1ab(ii,iii) + 2ab(ii,iii). Threatened by land reclamation and lake-level fluctuations resulting from water abstraction.
Remarks. The smallest European freshwater fish, reaching sexual maturity at 18 mm SL. Just 2.1 mm at hatching, larvae of this species are the smallest free-living European vertebrates.
Further reading. Economidis & Miller, 1990: 141 (description); Daoulas et al., 1993 (reproduction); Economou et al., 1994a: 26 (larvae); Economou et al., in Miller, 2004: 459 (biology).

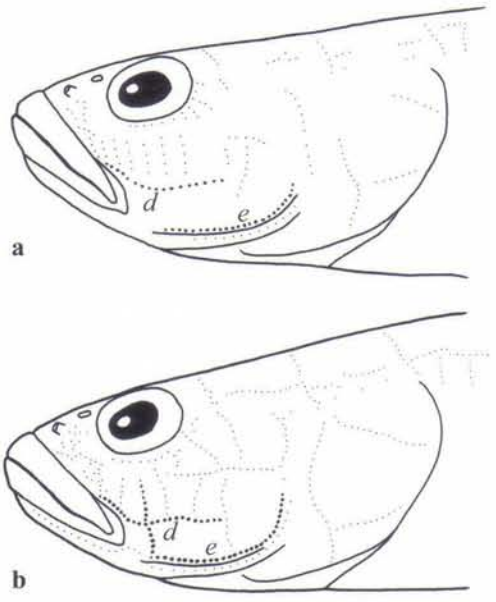

Figure 94 Sensory papillae on side of head: **a,** without vertical row on cheek between rows *d* and *e*, in most *Knipowitschia* species; **b,** with vertical row on cheek between rows *d* and *e*, in *K. bergi* (**a** after Ahnelt, 1991, **b** after Iljin, 1928, and Miller, 2004).

Key to species of *Knipowitschia* in European freshwaters

1a – Cephalic lateral line canals absent (Fig. 89a). 2

1b – Cephalic lateral line canals present (Fig. 89b). 4

2a – Flank and caudal peduncle covered by scales. ..... *K. milleri*

2b – Scales on body only under pectoral, caudal peduncle naked. 3

3a – 6 rays in first dorsal; 7½ branched rays in second dorsal; 9½ branched anal rays; body with 15–18 dark irregular bars in live breeding males. ..... *K. croatica*

3b – 7 rays in first dorsal; 8½ branched rays in second dorsal; 7–8½ branched anal rays; body with 10–15 dark irregular bars in live breeding males. ..... *K. punctatissima*

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4a – Squamation incomplete, scales present at most under pectoral, on caudal peduncle and along midlateral line. 5

4b – Flank and caudal peduncle covered by scales. 6

5a – Scales on body only under pectoral, sometimes a few scales in midlateral line on posterior part of body; body with irregular dark bars in live breeding males; posterior edge of pelvic-disc fraenum smooth (Greece: Thessaly). ..... *K. thessala*

5b – Scales on body under pectoral, on caudal peduncle, sometimes a single row along midlateral line; body with 8–10 vertically elongated (anteriorly) to oval (posteriorly) blotches in males; posterior edge of pelvic-disc fraenum crenated (Croatia: Neretva). ..... *K. radovici*

6a – Posterior oculoscapular canal absent (Fig. 92b-c). 7

6b – Posterior oculoscapular canal present (pores ρ^1-ρ^2; as in Fig. 92a). 11

7a – Anterior extremity of anterior oculoscapular canal behind middle of eye (pore κ; Fig. 92c). 8

7b – Anterior extremity of anterior oculoscapular canal in front of middle of eye (pore λ; Fig 92b). 9

8a – Five dark saddles across back; no transverse row of papillae on cheek extending downward beyond row *d* (Fig. 94a). ..... *K. goerneri*

8b – Body translucent in life, whitish with several black dots when preserved; a transverse row of papillae on cheek extending downward through row *d* and almost reaching row *e* (Fig. 94b). ..... *K. bergi*

9a – Anterior oculoscapular canals usually separated, with two median pores. ..... *K.* sp. Visovac

9a – Anterior oculoscapular canals united posteriorly, with a common median pore. 10

10a – Caudal symmetric; back naked in front of 4–8th ray of second dorsal. ..... *K. panizzae*

10b – Caudal asymmetric, upper part longer than lower part; back naked in front of origin of second dorsal. ..... *K. longecaudata*

11a – Body black with blue iridescence in live breeding males; live females with grey belly. ..... *K. cameliae*

11b – Body with 4–8 dark bars in live breeding males; live females with yellow belly. ..... *K. caucasica*

Knipowitschia bergi

Common name. Volga dwarf goby.

Diagnosis. Distinguished from other species of *Knipowitschia* in Caspian Sea basin by: ● anterior extremity of anterior oculoscapular canal behind middle of eye (pore κ; Fig. 92c) / ● a transverse row of papillae on cheek extending downward through row *d* and almost reaching row *e* (Fig. 94) / ○ body naked in front of first dorsal / ○ about 30 total scales in midlateral series / ○ caudal symmetric. Size up to 32 mm SL.

Distribution. Northern and southeastern Caspian Sea; deltas of Ural and Volga; along western coast southward to Daghestan.

Habitat. A near-pelagic coastal marine species; found in areas with different salinities, including fresh water.

Biology. Lives 1 year. Matures at 18–20 mm SL.

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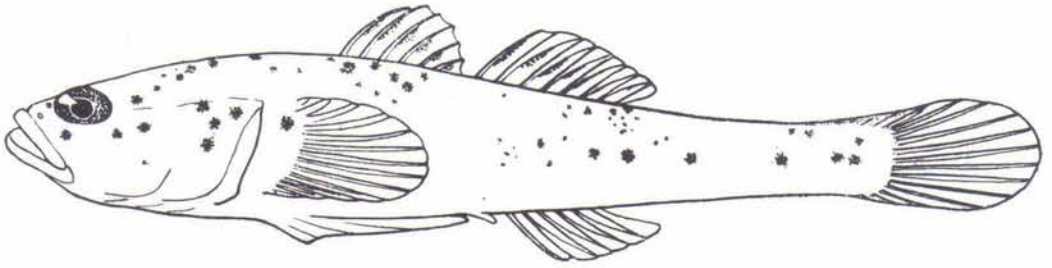
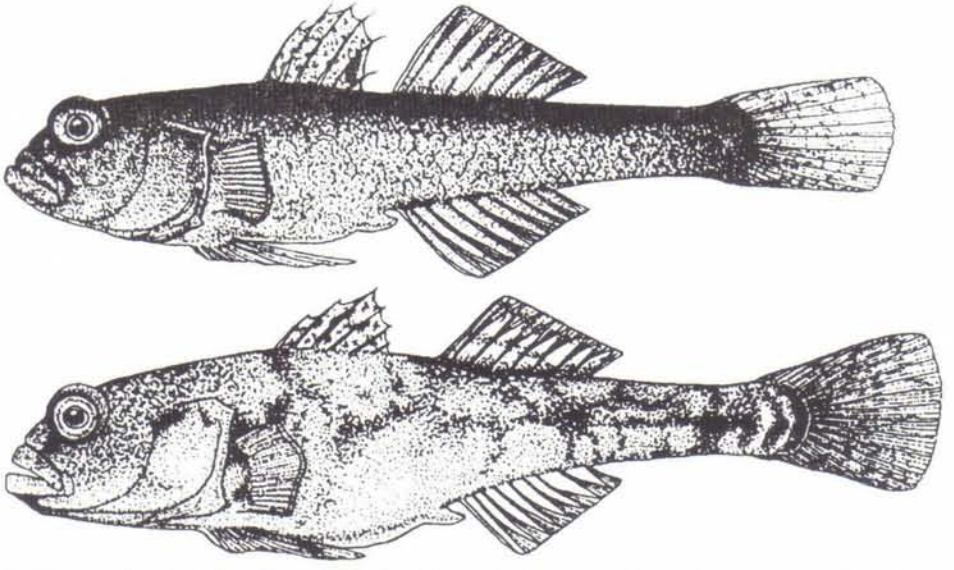


Knipowitschia bergi; Caspian Sea; ~30 mm SL. (from Iljin, 1928)



Knipowitschia cameliae; Portita, Romania; male, 30 mm SL (above) and female, 32 mm SL (below).
T. T. Nalbant

Spawns after first winter, in May – July, down to 2–7 m. Females probably lay 2–3 portions of eggs (0.4 × 1.0 mm), separately attached inside a mollusc shell. Adults probably die soon after spawning. Feeds on small crustaceans.

Conservation status. LC.

Remarks. Placed in a separate genus *Hyrcanogobius* by some authors on the basis of slightly different organisation of cephalic sensory pores.

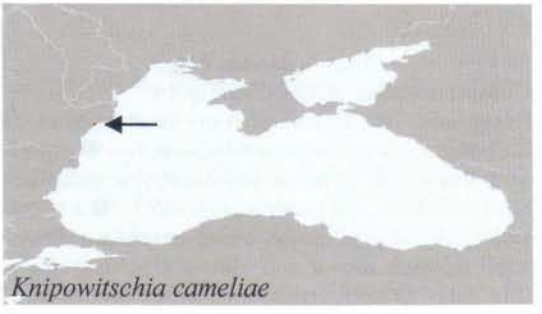
Further reading. Iljin, 1928: 44 (description); Miller & Pinchuk, in Miller, 2004: 432 (biology).

Knipowitschia cameliae

Common name. Danube delta dwarf goby.

Diagnosis. Distinguished from other species of *Knipowitschia* in Black Sea basin by: ● body black with blue iridescence in live breeding males / ○ back unscaled in front of rays 1–4 of second dorsal / ○ posterior oculoscapular canal or groove present / ○ females with grey belly in life / ○ 31–34 total scales in midlateral series. Size up to 32 mm SL.

Distribution. Romania: known from a single small



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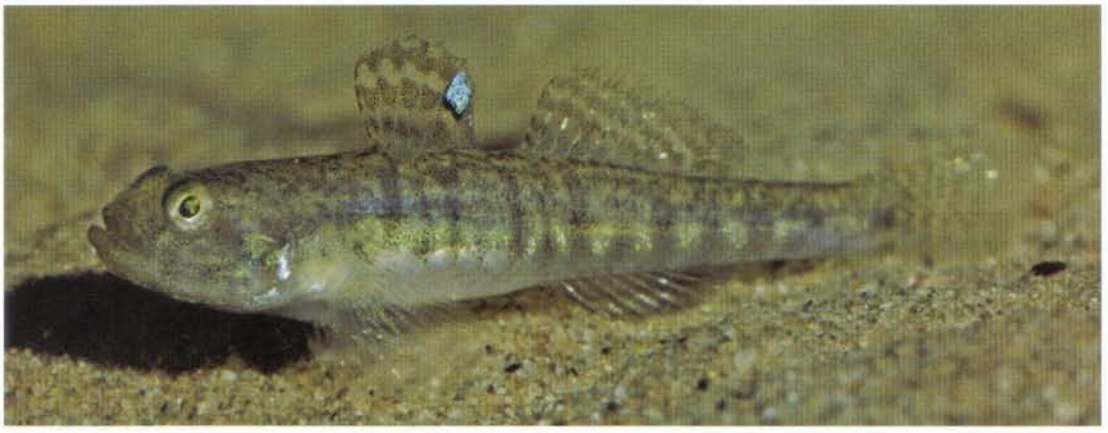

Knipowitschia caucasica; Lake Siut Giol, Romania; male, ~25 mm SL.

lagoon near Portita, south of Danube delta in the Golovita-Sinoe-Razelm Lake complex.
Habitat. A small and shallow lagoon behind coastal sand dunes with brackish water and mud bottom.
Biology. No data.
Conservation status. CR A2b; B1ab(v) + 2ab(v). Said to be extinct. Not found at type locality and adjacent water bodies since 1994. Presence in similar habitats elsewhere in Danube delta should be investigated.
Further reading. Nalbant & Otel, 1996 (description).

Knipowitschia caucasica

Common name. Caucasian dwarf goby.
Diagnosis. Distinguished from other species of *Knipowitschia* in Europe by: ❍ body with 4–8 dark bars in breeding males / ❍ back naked in front of origin of second dorsal / ❍ anterior extremity of anterior oculoscapular canal in front of middle of eye (pore λ) (Fig. 92b) / ❍ posterior oculoscapular canal present / ❍ females with yellow belly in life / ❍ 31–38 total scales in midlateral series. Size up to 50 mm SL.
Distribution. Saline, fresh and estuarine waters along coasts of Black, Azov, Caspian and Aegean Seas west to Aliakmon drainage (Greece); identity of populations from along the eastern shore of Adriatic questionable. Has been recorded from freshwater lakes and lowland rivers more than 100 km from coast. Introduced in Aral Sea (but now extirpated).
Habitat. Fresh to hypersaline waters (salinity up to 55 ‰) of lakes, estuaries and lagoons. Most abundant in shallow, well vegetated habitats.
Biology. Lives less than 2 years. Spawns after first winter, at 20–23 mm SL. Spawns in March – July, up to 4 portions of eggs. Eggs are attached to the roof of a cavity under stones, plant material or shells and are defended by male. Postlarvae are pelagic. Feeds on small invertebrates. In Trichonis Lake: on mud to gravel bottom, at depths less than 2 m; feeds mainly on copepods and larvae of the mussel *Dreissena polymorpha*.
Conservation status. LC.
Remarks. *Knipowitschia* is sometimes considered a synonym of *Pomatoschistus*. This is based on the study of *K. caucasica* only and awaiting the study of other species, we retain the genus as distinct. The variability (morphological and ecological) reported for *K. caucasica* suggests that this is a complex of several species.
Further reading. Economidis & Miller, 1990: 152 (systematics); Daoulas et al., 1993 (reproduction); Economou et al., 1994b (reproduction, Trichonis population); Ahnelt et al., 1995 (distribution, systematics); Vasilieva & Kuga, 2001 (osteology, systematics); Miller et al., in Miller, 2004: 343 (biology).

Knipowitschia croatica

Common name. Neretva dwarf goby.
Diagnosis. Distinguished from other species of *Knipowitschia* entering freshwater by: ❍ body with 15–18 dark, irregular bars in breeding males / ❍ no cephalic lateral line canals / ❍ scales on body only under pectoral / ❍ 6 rays in first dorsal / ❍ 7½ branched rays in second dorsal / ❍ 9½

Knipowitschia caucasica

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Knipowitschia croatica; Neretva, Bosnia-Herzegovina; male, ~35 mm SL.

Knipowitschia croatica; Neretva, Bosnia-Herzegovina; female, ~30 mm SL.

branched anal rays. Size up to 46.5 mm SL.
Distribution. Bosnia-Herzegovina: lower Neretva drainage. Croatia: upper Matica drainage, Neretva springs and Lake Bacina.
Habitat. Freshwater, in clear karstic springs, lakes, slow-flowing streams and small rivers.
Biology. Lives less than 2 years. Spawns after first winter, in February – May. Males defend eggs in cavities under stones, plant material or shells. Juveniles free swimming, adults benthic. May survive in underground waters during summer droughts.
Conservation status. VU B2ab(iii); D2.
Further reading. Mrakovčić et al., 1996 (description).

Knipowitschia goerneri

Common name. Corfu dwarf goby.
Diagnosis. Distinguished from other species of *Knipowitschia* entering freshwater by: ○ anterior extremity of anterior oculoscapular canal behind middle of eye (pore κ) (pore λ sometimes present) / ○ circumorbital and postorbital segments of oculoscapular canal separate, opening with pores α and α' (Fig. 92c) / ○ posterior oculoscapular canal absent / ○ no transverse row of papillae on cheek extending downward beyond row *d* (Fig. 92c) / ○ body with dark spots in breeding males / ○ flank and caudal peduncle entirely covered by scales / ○ 32–33 total scales in midlateral series. Size up to 22 mm SL.
Distribution. Greece: freshwater spring southwest

Knipowitschia croatica

Knipowitschia goerneri

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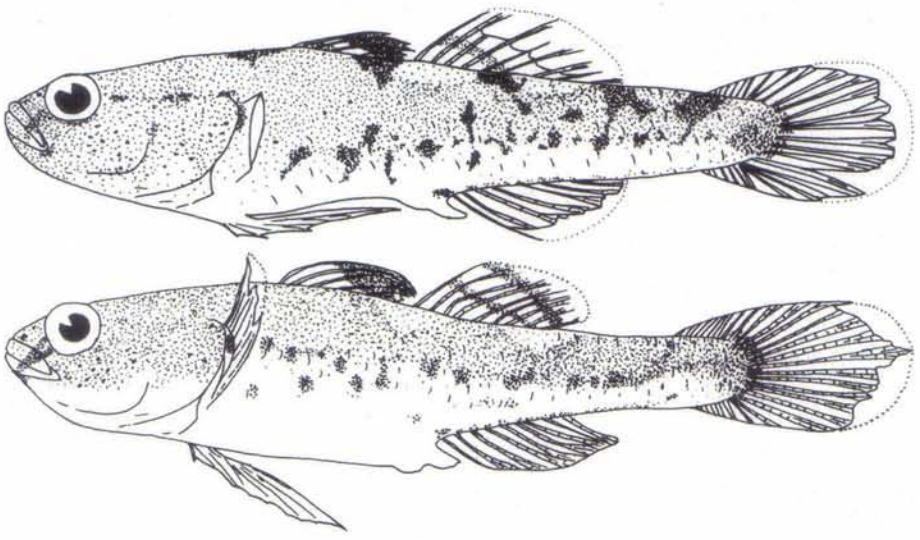

Knipowitschia goerneri; Corfu Island, Greece; male, 18 mm SL (above) and female, 18 mm SL (below).
H. Ahnelt

Knipowitschia longecaudata; Lake Sinoe, Romania; male, ~30 mm SL.

of Korissias lagoon, southern Corfu Island.
Habitat. Freshwater spring and small brook flowing towards nearby lagoon.
Biology. No data.
Conservation status. DD. Not observed at only known locality since 1983, survey of adjacent areas needed.
Further reading. Ahnelt, 1991: 266 (description).

Knipowitschia longecaudata

Common name. Longtail dwarf goby.
Diagnosis. Distinguished from other species of *Knipowitschia* entering freshwater by: ● caudal asymmetric, upper part longer than lower part / ○ anterior extremity of anterior oculoscapular canal in front of middle of eye (pore λ) / ○ posterior oculoscapular canal absent / ○ back naked in front of origin of second dorsal / ○ body with 4–8 dark bars in live breeding males / ○ 33–40 total scales in midlateral series. Size up to 40 mm SL.
Distribution. Caspian, Azov and Black Sea basins. Close to sea.
Habitat. Fresh to saline water of coastal lakes, reservoirs, estuaries and lagoons, in shallow, well vegetated habitats.
Biology. Lives less than 2 years. Spawns after first winter, at 20 mm SL. Spawns in March – July. Females may spawn several times during a season. Males defend eggs in cavities under stones, plant material or mollusc shells. Eggs hatch at 3.0–3.8 mm. Feeds on small invertebrates.
Conservation status. LC.
Further reading. Miller, 2004: 382 (description, biology).

Knipowitschia longecaudata

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Knipowitschia milleri; lower Acheron, Greece; female, 27 mm SL.

Knipowitschia panizzae; Lake Trasimeno, Italy; male, ~20 mm SL.

Knipowitschia milleri

Common name. Acheron spring goby.

Diagnosis. Distinguished from other species of *Knipowitschia* entering freshwater by: / ❍ predorsal region and back naked / ❍ no cephalic lateral line canals / ❍ 6 rays in first dorsal / ❍ 7–9½ branched rays in second dorsal / ❍ 7–8½ branched anal rays. Size up to 26 mm SL.

Distribution. Greece: lower stretch of River Acheron.

Habitat. Clear, nearly stagnant, temperate, sometimes slightly brackish waters with abundant submerged vegetation and sand or mud bottom.

Biology. Lives up to 2 years. Spawns in February – March. Juveniles free swimming, adults benthic. Feeds on chironomid larvae and small crustaceans.

Conservation status. CR B1ab(i,ii,iii) + 2ab (i,ii,iii). Habitat largely drained and filled with garbage.

Further reading. Ahnelt & Bianco, 1990 (description); Miller et al., in Miller, 2004: 399 (biology).

Knipowitschia panizzae

Common name. Adriatic dwarf goby.

Diagnosis. Distinguished from other species of *Knipowitschia* entering freshwater by: ❍ posterior oculoscapular canal absent / ❍ anterior extremity of anterior oculoscapular canal in front of middle of eye (pore λ) / ❍ body with dark spots or bars in live breeding males / ❍ back naked in front of 4–8th ray of second dorsal / ❍ 32–39 total scales in midlateral series. Size up to 37 mm SL.

Distribution. Italian, Slovenian and Croatian coast of Adriatic and Ionian Seas. Recorded southward to Basilicate (Italy) and Evinos estuary (Greece), but the latter record needs confirmation. Introduced in Lake Trasimeno (central Italy) and a few

Knipowitschia milleri

Knipowitschia panizzae

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Knipowitschia punctatissima; Stella drainage, Italy; male, ~40 mm SL.

Knipowitschia radovici; Norin, Neretva drainage, Croatia; 28 mm SL. M. Kovačić

localities on Tyrrhenian slope.
Habitat. Fresh to brackish water of streams, lakes, estuaries and lagoons in shallow, well vegetated habitats.
Biology. Lives less than 2 years. Spawns after first winter, in April – August. Females may repeat spawning every 10–15 days during a season. Males defend eggs in cavities under stones, plant material or shells. Males may overturn and clean suitable shells for spawning. Shells are covered with substrate by males after spawning. Postlarvae pelagic. Feeds on small invertebrates.
Conservation status. LC.
Further reading. Miller, 1972 (description, systematics), 2004: 405 (biology).

Knipowitschia punctatissima

Common name. Italian spring goby.
Diagnosis. Distinguished from other species of *Knipowitschia* in Europe by: ○ no cephalic lateral line canals / ○ scales on body only under pectoral / ○ body with 10–15 dark, irregular bars in live breeding males / ○ 7 rays in first dorsal / ○ 8½ branched rays in second dorsal / ○ 7–8½ branched anal rays. Size up to 45 mm SL.
Distribution. Coastal lowlands of northeastern Italy, very localised in karstic springs and streams between Brenta and Stella drainages.
Habitat. Freshwater, in small clear karstic springs and streams, densely vegetated channels and slow-flowing streams.
Biology. Lives less than 2 years. Spawns after first winter, in February – July. Females may spawn more than once during a season. Males defend eggs in cavities under stones, plant material or shells. Postlarvae pelagic. Feeds on small invertebrates.
Conservation status. NT. Threatened by water abstraction, which lowers the water table, resulting in desication of some springs.
Further reading. Lugli et al., 1997 (reproduction); Gandolfi et al., 1985 (biology); Miller, 2004: 415 (description, biology).

Knipowitschia radovici

Common name. Norin goby.
Diagnosis. Distinguished from other species of *Knipowitschia* entering freshwater by: ○ cephal-

Knipowitschia punctatissima

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Knipowitschia thessala; Pinios (Thessaly), Greece; male, ~35 mm SL.

Knipowitschia thessala; Pinios (Thessaly), Greece; female, ~30 mm SL.

ic lateral line canals present (Fig. 92b) / ○ scales on body under pectoral, on caudal peduncle, sometimes a single row along midlateral line / ○ body with 8–10 vertically elongated (anteriorly) to oval (posteriorly) blotches in males / ○ posterior edge of pelvic-disc fraenum crenated / ○ 6 rays in first dorsal / ○ 8½ branched rays in second dorsal / ○ 8½ branched anal rays. Size up to 28 mm SL.

Distribution. Croatia: Neretva drainage: stream Norin.

Habitat. Outflow of a karstic spring, discharging 3.5–6.0 m/s in summer, down to 5.5 m, with gravel to mud-gravel bottom.

Biology. No data. Adults observed in deepest parts of stream, juveniles in shallow areas among vegetation.

Conservation status. VU D2.

Further reading. Kovačić, 2005a: 275 (description).

Knipowitschia thessala

Common name. Thessaly goby.

Diagnosis. Distinguished from other species of *Knipowitschia* entering freshwater by: ○ cephalic lateral line canals present (Fig. 92b) / ○ scales on body under pectoral, sometimes a few scales in lateral midline on posterior part of body / ○ body with irregular dark bars in live breeding males / ○ posterior edge of pelvic-disc fraenum smooth / ○ 6 rays in first dorsal / ○ 8½ branched rays in second dorsal / ○ 8½ branched anal rays. Size up to 37 mm SL.

Distribution. Greece: Pinios drainage (Thessaly).

Habitat. Freshwater; small streams with stone bottom.

Biology. No data.

Conservation status. EN B2ab(ii,iii,v).

Further reading. Economidis & Miller, 1990: 158 (description).

Knipowitschia radovici

Knipowitschia thessala

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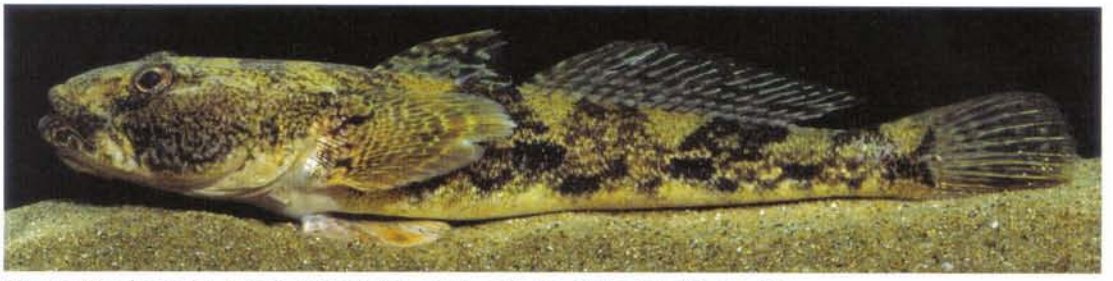
Knipowitschia sp. Visovac; Visovac Lake, Croatia; male, ~40 mm SL.



Mesogobius batrachocephalus; Black Sea north of Varna, Bulgaria; 190 mm SL.

Knipowitschia sp. Visovac

Common name. Visovac goby.

Diagnosis. Distinguished from other species of *Knipowitschia* entering freshwater by: ○ cephalic lateral line canals present (Fig. 92b) / ● anterior oculoscapular canals usually separated posteriorly, with two median pores (λ) or a single wide pore (κ) / ○ back naked in front of 4–8th ray of second dorsal / ○ 34–38 total scales in midlateral series / ○ body with regular narrow dark bars on body in front of second dorsal in live breeding males / ○ posterior edge of pelvic-disc fraenum smooth / ○ 6 rays in first dorsal / ○ 7–8½ branched rays in second dorsal / ○ 7–8½ branched anal rays / ○ flank and caudal peduncle covered by scales. Size up to 45 mm SL.

Distribution. Croatia: Lake Visovac and tributaries in middle Krka drainage.

Habitat. Freshwater; lacustrine on mud and stone bottom.

Biology. No data.

Conservation status. CR B1ab(v)*.

Further reading. Mrakovčić et al., 2006: 92 (distribution; as *K. mrakovcici*).

Mesogobius batrachocephalus

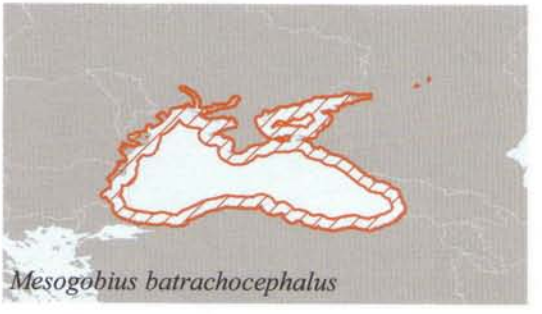
Common name. Knout goby.

Diagnosis. Distinguished from species of similar genus *Neogobius* in freshwaters in Black Sea basin by: ● 8–10 vertical rows of papillae in suborbital area (Fig. 93b) / ● 72–85 total scales in midlateral series / ○ nape naked. Size up to 345 mm SL.

Distribution. Black and Azov Seas; lower South Bug and freshwater Lake Siut Giol on Romanian coast.

Habitat. Inshore habitats, estuaries, brackish- and fresh-water lagoons on sand or rock bottom. Often very deep in summer (down to 100 m). Rarely

Knipowitschia sp. Visovac



Mesogobius batrachocephalus

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in pure freshwater.
Biology. Lives up to 8 years. Spawns for the first time at 3 years. Spawns in February – May, only once a year. Eggs large, deposited under or between stones. Feeds predominantly on fish.
Conservation status. LC. Regionally threatened by periods of hypoxia following algal blooms.

Remarks. *M. nonultimus* (nape scaled) from Caspian basin, usually listed as a subspecies of *M. batrachocephalus*, is a distinct species. It does not enter freshwaters.
Further reading. Porumb, 1961 (biology); Bănărescu, 1964 (biology, distribution); Pinchuk et al., in Miller, 2004: 109 (biology).

Key to species of *Neogobius* entering freshwater in Europe

N. ratan, *N. platyrostris* and *N. cephalargoides* are known from brackish water in the Black and Azov Sea basins, *N. caspius* and *N. ratan* in the Caspian basin. *N. cyrius* occurs in all southern tributaries of the Caspian and *N. rhodioni* in rivers of the Black Sea basin in Russia, south of the Greater Caucasus, both outside Europe. *Neogobius* might be a polyphyletic assemblage and its systematics is still not settled.

1a – First branched ray of second dorsal about twice as long as penultimate ray. 2
1b – First branched ray of second dorsal about as long as penultimate ray. 3

2a – First dorsal without small black spot in posterior part. ..... *N. fluviatilis*
2b – First dorsal with small black spot in posterior part, at least in juveniles. ..... *N. pallasi*

3a – First dorsal with large black spot in posterior part. ..... *N. melanostomus*
3b – First dorsal without large black spot in posterior part. 4

4a – Midline of nape naked in front of preoperculum (Fig. 95); diagonal bars on body irregular in position and shape. ..... *N. gymnotrachelus*
4b – Predorsal area and nape completely covered by scales; no bars on body. 5

5a – Pelvic-disc fraenum with small, rounded lobes whose length is less than 1/6 of fraenum width at base (Fig. 96a). ..... *N. syrman*
5b – Pelvic-disc fraenum with angular lobes whose length is 1/6–1/2 of fraenum width at base (Fig. 96b). 6

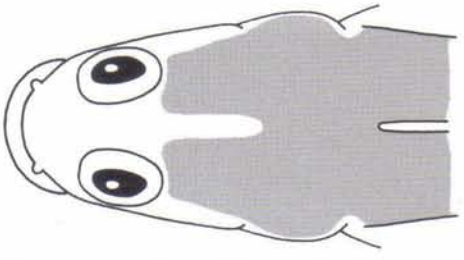

Figure 95 Scalation on nape missing on dorsal midline in some species of Gobiidae.

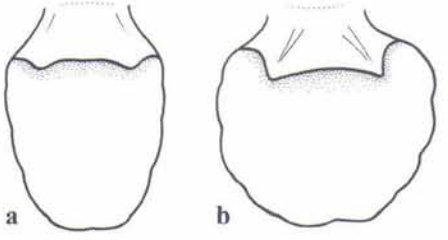

Figure 96 Pelvic disc fraenum in *Neogobius* species. **a,** with small rounded lobes; **b,** with angular lobes.

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Neogobius constructor; Kuban drainage, Russia; male, ~85 mm SL.

6a – Predorsal area and nape covered by ctenoid scales. ..... *N. kessleri*

6b – Predorsal area and nape covered by cycloid scales. 7

7a – 68–72 + 3–4 scales in midlateral series. ..... *N. gorlap*

7b – 58–70 + 2–4 scales in midlateral series. 8

8a – Pelvic disc reaching 40–60 % of distance between its origin and anus; snout length 1.5–1.9 times in eye diameter. ..... *N. constructor*

8b – Pelvic disc reaching 80–100 % of distance between its origin and anus; snout length 1.3–1.5 times in eye diameter. ..... *N. eurycephalus*

Neogobius constructor

Common name. Caucasian goby.

Diagnosis. Distinguished from other species of *Neogobius* entering freshwater in Black Sea basin by: ● pelvic disc reaching 40–60 % of distance between its origin and anus / ● predorsal area and nape completely covered by cycloid scales / ● pelvic-disc fraenum with angular lobes whose length is 1/6–1/2 of fraenum width at base (Fig. 96b) / ● 58–70 + 2–4 scales in midlateral series / ● snout length 1.5–1.9 times in eye diameter. Size up to 200 mm SL.

Distribution. In Europe, western tributaries of River Kuban in northern Caucasus. In Asia, coastal Black Sea drainages of southern Caucasus from Chorokh to Psyrtskha.

Habitat. Freshwater, in a wide variety of flowing waters from cold hill to foot hill streams. Never found in brackish water.

Biology. No data. Males guard eggs in gravel or rocky cavities.

Conservation status. LC. Very restricted distribution in European and Asian Caucasus. Locally abundant in suitable habitats.

Further reading. Berg, 1949: 1087 (description; as *N. cephalarges constructor*, in part); Vasilieva & Vasiliev, 1994: 753 (description); Vasilieva & Vasiliev, in Miller, 2003: 193 (distribution, description).

Neogobius constructor

Neogobius eurycephalus

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Neogobius eurycephalus; estuary of Obitochnaya, Ukraine; male, 71 mm SL.

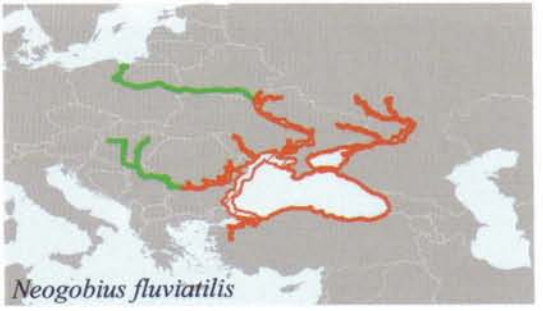
Neogobius eurycephalus; Danube delta, Romania; female, ~65 mm SL.

Neogobius eurycephalus

Common name. Ginger goby.

Diagnosis. Distinguished from other species of *Neogobius* entering freshwater in Black Sea basin by: O predorsal area and nape completely covered by cycloid scales / O pelvic disc reaching 80–100 % of distance between its origin and anus / O pelvic-disc fraenum with angular lobes whose length is 1/6–1/2 of fraenum width at base (Fig. 96b) / O 58–70 + 2–4 scales in midlateral series / O snout length 1.3–1.5 times in eye diameter / O first branched ray of second dorsal about as long as penultimate ray / O no black spot on posterior part of first dorsal. Size up to 200 mm SL.

Distribution. Azov and northern Black Sea basins from Bulgaria to eastern Crimea. In freshwater only in Danube delta.



Neogobius fluviatilis

Habitat. Inshore habitats, brackish lagoons, estuaries and lower part of large rivers, usually associated with rock bottom or sunken trees.

Biology. Spawns for the first time at 2 years. Spawns in December – April. Females may repeat spawning during a season. Feeds mostly on crustaceans.

Conservation status. LC.

Further reading. Pinchuk et al., in Miller, 2003 (biology, description).

Neogobius fluviatilis

Common name. Pontian monkey goby.

Diagnosis. Distinguished from other species of *Neogobius* entering freshwater in Black Sea basin by: ● first branched ray of second dorsal about twice as long as penultimate ray / O nape completely scaled / O pelvic-disc fraenum with small, rounded lobes whose length is less than 1/6 of fraenum width at base (Fig. 96a) / O pelvic disc reaching 90–100 % of distance between its origin and anus / O 55–61 + 2–4 scales in midlateral series / O no black spot in posterior part of first dorsal. Size up to 200 mm SL.

Distribution. Azov and Black Sea basins. Usually close to estuaries. Invasive in rivers of northern Black Sea basin, recorded in 1997 from middle Vistula (Poland), which it reached from Dniepr via a navigation canal. In Danube upriver to Hun-

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Neogobius fluviatilis; Obitochnaya, Ukraine; nuptial male, 147 mm SL.

Neogobius fluviatilis; Lake Sinoe, Romania; female, ~80 mm SL.

Neogobius gorlap; Volga delta, Russia; 134 mm SL.

gary, in Dniepr up to Belarus. Introduced in Lake Balaton (Hungary) around 1970.

Habitat. Inshore habitats, estuaries, brackish- and fresh-water lagoons and lakes, large to medium sized rivers and streams, on sand or mud bottom. Mostly found on open sand or mud bottom. One of the most abundant fish species in lowland rivers.

Biology. Lives up to 5 years. Spawns for the first time at 2 years. Spawns in April – July, locally until September, when temperature rises above 13°C. Females may repeat spawning during a season. Males have completely black body with yellow fin margins during spawning season. Adhesive eggs are deposited on stones, shells and aquatic plants. Males excavate nests under any kind of hard substrate and guard eggs until hatching. Feeds on a wide variety of invertebrates, especially molluscs.

Conservation status. LC.

Further reading. Ahnelt et al., 1998 (invasion); Danilkiewicz, 1998 (record from Poland); Pinchuk et al., in Miller, 2003 (biology, description).

Neogobius gorlap

Common name. Caspian bighead goby.

Diagnosis. Distinguished from other species of *Neogobius* entering freshwater in Caspian Sea basin by: ○ predorsal area and nape completely covered by ctenoid scales / ○ pelvic-disc fraenum with angular lobes whose length is 1/6–1/2 of fraenum width at base (Fig. 96b) / ○ pelvic disc reaching 75–95 % of distance between its origin and anus / ○ 68–72 + 3–4 scales in midlateral series /

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Neogobius gymnotrachelus; Danube delta, Romania; female, ~70 mm SL.

○ snout length 1.5–1.6 times eye diameter / ○ interorbital distance 0.8–0.9 times eye diameter / ○ first branched ray of second dorsal about as long as penultimate ray / ○ no black spot on posterior part of first dorsal. Distinguished from closely related *N. kessleri* from Black Sea basin in having a distinctive karyotype, some osteological characters and scales on opercle and anterior part of nape usually cycloid (vs. ctenoid). Size up to 200 mm SL.

Distribution. Caspian basin. In Volga upriver to Astrakhan until 1977, since spreading upriver to Lakes Ivankovskoje and Rybinskoje (2000). Invaded Don drainage (Black Sea basin) through Volga-Don canal (first record in 1972). Now abundant in Lake Tsimlyansk and lower Don.

Habitat. Inshore habitats, estuaries, brackish- and fresh-water lagoons and lakes, large rivers, harbours, on rock bottom. Mainly found on well vegetated or rock bottom.

Biology. Most females spawn for the first time at 1 year, males at 2 years. Spawns in April – May, rarely until July. Adhesive eggs are deposited on stones, shells and aquatic plants. Males guard eggs until hatching. Feeds mostly on small fish, as well as on a wide variety of invertebrates.

Conservation status. LC.

Further reading. Vasilieva & Vasiliev, 1996: 264 (description, as *N. iljini*); Kottelat, 1997: 178 (nomenclature); Boldyrev, 2002: 99 (invasion); Vasilieva & Vasiliev, in Miller, 2003 (biology, description).

Neogobius gymnotrachelus

Common name. Racer goby.

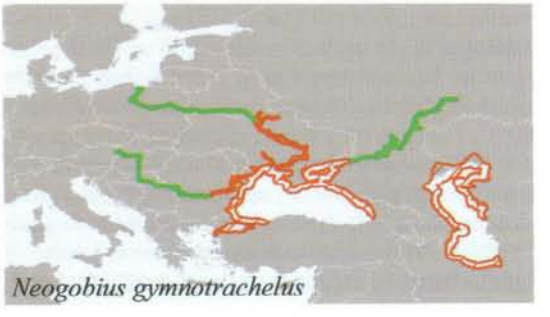
Diagnosis. Distinguished from other species of *Neogobius* entering freshwater in Europe by: ● midline of nape naked in front of preoperculum / ● diagonal bars on body irregular in position and shape / ○ pelvic-disc fraenum with small, rounded lobes whose length is less than 1/6 of fraenum width at base (Fig. 96a) / ○ 54–62 + 2–3 scales in midlateral series / ○ first branched ray of second dorsal about as long as penultimate ray / ○ first dorsal without black spot in posterior part. Size up to 160 mm SL.

Distribution. Black, Azov and Caspian Sea basins. Since late 1990s, invasive immigrant in rivers of northern Black Sea basin. In Danube up to Vienna (about 2000 km from sea), in Dniepr up to Belarus. Recorded in 1996 from middle Vistula in Poland, where it arrived from Dniepr via a navigation canal. Fast spreading in Vistula observed in 2002. Invaded Volgograd reservoir through Volga-Don canal.

Habitat. Mosly in freshwater and brackish water with low salinity (< 2 ‰). Estuaries, brackish- and fresh-water lagoons and lakes, large rivers up to small, fast-flowing streams, on sand or mud bottom. Mainly found in well vegetated or high-complexity habitats. Abundant in backwaters and still channels.

Biology. Lives up to 4–5 years. Spawns for the first time at 2 years. Spawns in April – June, occasionally until mid-August. Females may repeat

Neogobius gorlap



Neogobius gymnotrachelus

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Neogobius kessleri; Danube drainage, Hungary; ~90 mm SL. Z. Sallai

spawning during a season. Usually spawns only for a single season. Adhesive eggs are deposited on stones, shells and aquatic plants. Males guard eggs until hatching. Feeds on a wide variety of invertebrates, especially molluscs.

Conservation status. LC. Invasive in central and eastern Europe.

Remarks. Future investigations may show that *N. g. macrophthalmus* from Caspian basin is a distinct species.

Further reading. Danilkiewicz, 1996 (records from Poland); Zweimüller et al., 2000 (invasion); Ahnelt et al., 2001 (description, invasion); Pinchuk et al., in Miller, 2003 (biology, description).

Neogobius kessleri

Common name. Pontian bighead goby.

Diagnosis. Distinguished from other species of *Neogobius* entering freshwater in Black Sea basin by: O predorsal area and nape completely covered by ctenoid scales / O pelvic-disc fraenum with angular lobes whose length is 1/6–1/2 of fraenum width at base (Fig. 96b) / O pelvic disc reaching 75–95 % of distance between its origin and anus / O 68–72 + 2–4 scales in midlateral series / O snout length 1.5–2.0 times eye diameter / O first branched ray of second dorsal about as long as penultimate ray / O first dorsal without black spot in posterior part. Size up to 200 mm SL.

Distribution. Black Sea basin: Danube, Dniestr, South Bug and Dniepr drainages. Since late 1990s, range regularly expanding upstream in Danube drainage, in 1999 recorded for first time in Germany (2400 km from sea), in 2005 in upper reaches of Rhine drainage close to canal connecting it with Danube, and in 2006 in the lower reaches of Rhine. In Dniepr up to Kiev. Absent in Azov Sea basin.

Habitat. Mostly in freshwater and brackish water with very low salinity (less than 2 ‰). Estuaries, brackish- and fresh-water lagoons and lakes, large rivers, harbours, on rock bottom. Mostly found on well vegetated or rock bottom in still waters as well as in rapids.

Biology. Spawns for the first time at 2 years. Spawns in March – May. Adhesive eggs deposited on stones, shells and aquatic plants. Males guard eggs until hatching. Feeds on a wide variety of invertebrates. Larger individuals take mostly small fish.

Conservation status. LC.

Remarks. *N. gorlap* from Caspian Sea, often treated as a subspecies of *N. kessleri*, is a distinct species.

Further reading. Vasilieva & Vasiliev, 1996: 267 (diagnosis); Zweimüller et al., 1996 (invasion); Weissenbacher et al., 1998 (invasion); Ahnelt et al., 1998 (invasion); Seifert & Hartmann, 2000 (invasion); Vasilieva & Vasiliev, in Miller, 2003 (biology, description).

Neogobius melanostomus

Common name. Round goby.

Diagnosis. Distinguished from other species of *Neogobius* entering freshwater in Europe by: O first dorsal with large black spot on posterior part / ● 45–54 + 2–3 scales in midlateral series / O nape completely scaled / O pelvic-disc fraenum with small, rounded lobes whose length is less than 1/6 of fraenum width at base (Fig. 96a) / O first branched ray of second dorsal about as long as penultimate ray. Size up to 220 mm SL.

Distribution. Azov, Black and Caspian Sea basins. Invasive in Baltic basin, which it reached via navigation canals. Reached westwards to German Baltic coast in 2002. Recently recorded in lower parts of rivers in Gulf of Gdansk (Poland). Also

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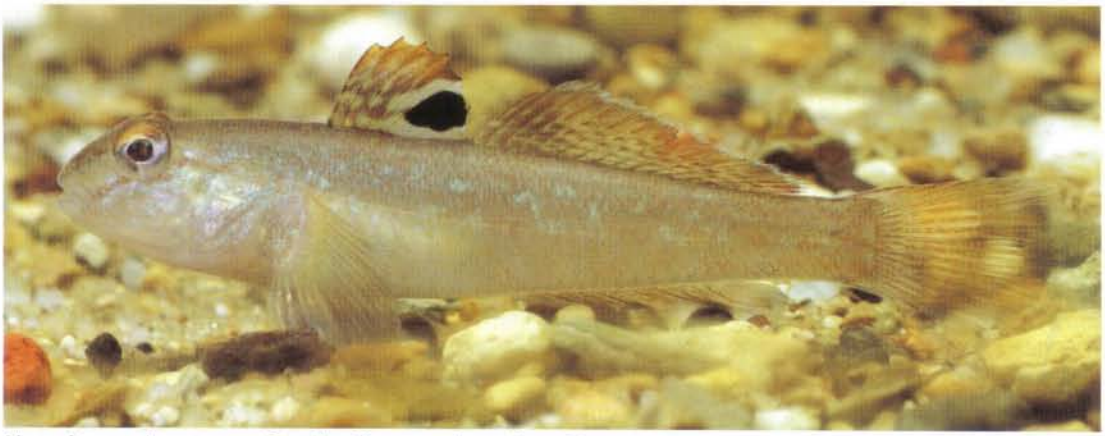
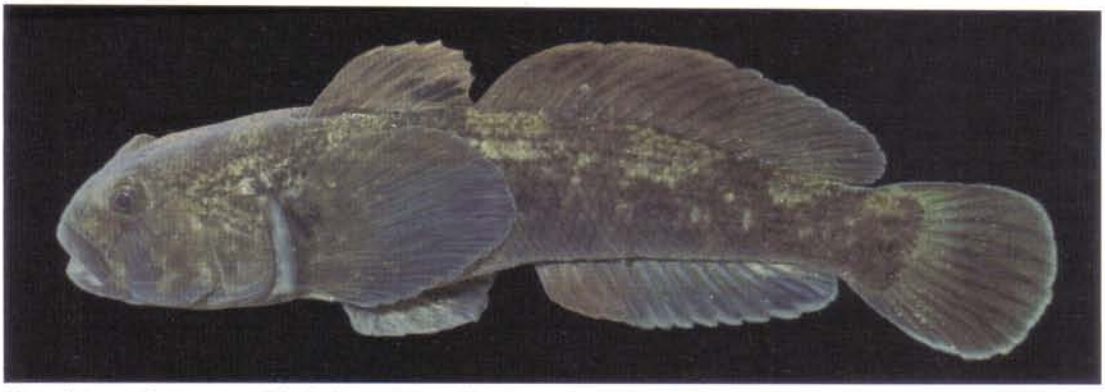


Neogobius melanostomus; Danube, Germany; juvenile, ~80 mm SL. A. Hartl



Neogobius melanostomus; Black Sea at Mangalia, Romania; male, ~160 mm SL.

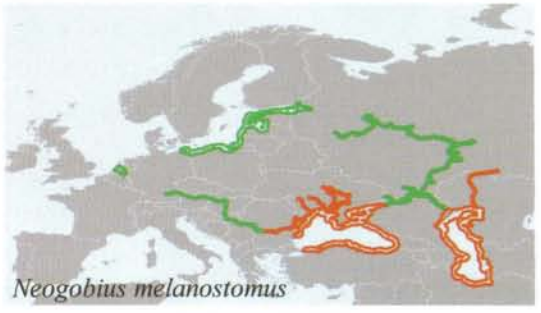
moving upwards in rivers of its original range; in Volga upstream to Moscow and north to Lake Rybinskoye; in Dniepr up to Belarus, in Danube reached Austria in 2000 and Germany in 2004. Accidentally arrived in North America in 1991 and lowermost Rhine (Netherlands) in 2004 with ballasts water in ships.

Habitat. Inshore habitats, estuaries, brackish- and fresh-water lagoons and lakes, large rivers, harbours, on sand or rock bottom. To 50–60 m deep in Black Sea during winter. Mostly found on well vegetated or rock bottom.

Biology. Lives up to 4 years. Males reproduce for the first time at 3–4 years, females at 2–3. Spawns in April – September. Males have entirely black body during spawning season. Females may repeat spawning during a season every 18–20 days. Adhesive eggs are deposited under or between stones, shells and aquatic plants. Males guard eggs until hatching, in 2–3 weeks. Males usually die after spawning season. Feeds on a wide variety of invertebrates and small fish, mostly on molluscs. Egg clutches are supposed to be occasionally transported attached to the hull of ships, facilitating the invasion of new areas.

Conservation status. LC.

Further reading. Tsepkin et al., 1992 (invasion); Charlebois et al., 1997 (review); Wiesner et al., 2000 (invasion); Pinchuk et al., in Miller, 2003 (biology, description).



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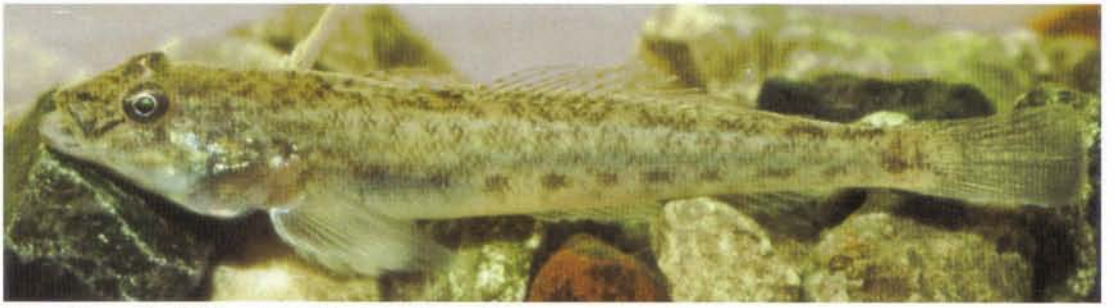


Neogobius pallasi; Volga delta, Russia; ~50 mm SL.

Neogobius syrman; Sea of Azov at Berdyansk, Ukraine; male, 160 mm SL.

Neogobius pallasi

Common name. Caspian monkey goby.

Diagnosis. Distinguished from other species of *Neogobius* entering freshwater in Caspian basin by: ● first branched ray of second dorsal about twice as long as penultimate ray / ○ nape completely scaled / ○ pelvic-disc fraenum with small, rounded lobes whose length is less than 1/6 of fraenum width at base (Fig. 96a) / ○ pelvic disc reaching 90–100 % of distance between its origin and anus / ○ 55–63 + 2–3 scales in midlateral series / ○ first dorsal with small black spot on posterior part, at least in juveniles. Distinguished from closely related *N. fluviatilis* from Black Sea basin by: first dorsal with black spot in posterior part, at least in juveniles. Size up to 200 mm SL.

Distribution. Caspian basin; common in Volga drainage, upriver to Moscow. Introduced in Aral basin in 1954.

Habitat. Inshore habitats, estuaries, brackish- and fresh-water lagoons and lakes, large to medium-size rivers, on sand or mud bottom. Usually on open sand or sand-shell bottom.

Biology. Lives up to 3 years. Spawns for the first time at 1 year, rarely at 2. Spawns in April – September. Individual females may repeat spawning during a season. Adhesive eggs are deposited on stones, shells and aquatic plants. Males guard eggs until hatching. Feeds on a wide variety of invertebrates (mainly crustaceans and insect larvae) and small fish.

Conservation status. LC.

Further reading. Pinchuk et al., in Miller, 2003 (biology, description; as *N. fluviatilis*, in part).

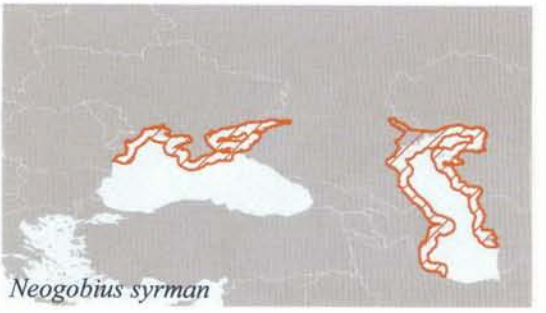
Neogobius syrman

Common name. Syrman goby.

Diagnosis. Distinguished from other species of *Neogobius* entering freshwater in Europe by: ○ interorbital distance equal to eye diameter / ○ nape completely scaled / ○ pelvic-disc fraenum with small, rounded lobes whose length is less than 1/6 of fraenum width at base (Fig. 96a) / ○ pelvic disc reaching 60–70 % of distance between its origin and anus / ○ first branched ray of second dorsal about twice as long as penultimate ray / ○ 57–67 + 2–3 scales in midlateral series. Size up to 220 mm SL.

Distribution. Azov, Black and Caspian Sea basins.

Habitat. Inshore habitats, estuaries, brackish- and fresh-water lagoons, large rivers on mud bottom.



Neogobius syrman

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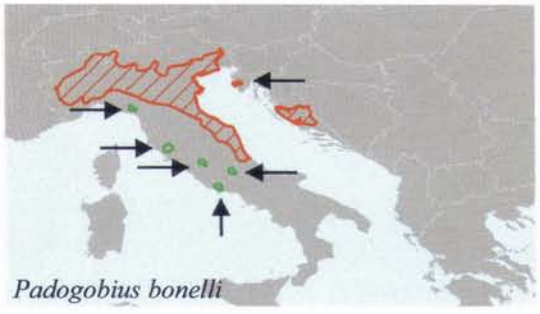
Padogobius bonelli; Lake Garda, Italy; male, ~60 mm SL. A. Hartl

Padogobius bonelli; Ricica, Croatia; female, ~35 mm SL.

Padogobius nigricans; Arno drainage, Italy; ~35 mm SL.



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Restricted to coastal areas.
Biology. Lives up to 4 years. Spawns for the first time at 1–2 years. Spawns in March – June. Females may spawn twice during a season. Adhesive eggs are deposited under or between stones, shells and aquatic plants. Males guard eggs until hatching. Feeds on a wide variety of invertebrates and small fish.
Conservation status. LC.
Remarks. Records from upper Danube refer to *N. gymnotrachelus*.
Further reading. Pinchuk et al., in Miller, 2003 (biology, description).

Padogobius bonelli

Common name. Padanian goby.
Diagnosis. Distinguished from other Gobiidae in freshwaters of Adriatic basin and Italy by: ○ no cephalic lateral line canals (Fig. 89b) / ○ 11–12½ branched rays in second dorsal / ○ 29–43 total scales in midlateral series / ○ caudal peduncle completely scaled. Size up to 76 mm SL.
Distribution. Northern Adriatic basin, from Vomano (Italy) to Krka drainages (Croatia); subalpine lakes in Po drainage. Introduced in most of western and central Italy.
Habitat. Exclusively freshwater. In a wide variety of stream, river and lake habitats with dense vegetation or coarse gravel.
Biology. Spawns for the first time at 1 year. Spawns in April – July, when temperature reaches 20°C. Females may spawn several times during a season. Adhesive eggs are deposited under or between stones, shells and aquatic plants. Males guard eggs until hatching. Males produce sounds when spawning and defending the nest. Feeds on a wide variety of benthic invertebrates.
Conservation status. LC. Generally not threatened, but populations of subalpine lakes drastically regressed.
Remarks. Earlier known under the incorrect name *P. martensii*.
Further reading. Gandolfi & Tongiorgi, 1974 (description, biology); Bianco & Miller, 1990 (distribution); Kottelat, 1997: 179 (nomenclature); Miller, 2004: 36 (biology).

Padogobius nigricans

Common name. Etrurian goby.
Diagnosis. Distinguished from other species of Gobiidae in freshwaters of Adriatic basin and western Italy by: ○ cephalic lateral line canals present (Fig. 92b) / ○ 11–12½ branched rays in second dorsal / ● 44–49 total scales in midlateral series / ○ caudal peduncle completely scaled. Size up to 76 mm SL.
Distribution. Central Italy: Tevere, Arno and Ombrone drainages, on Tyrrhenian slope. Usually very locally distributed.
Habitat. Exclusively freshwater, in shallow, well vegetated shores of small to medium-size streams with moderate current.
Biology. Spawns for the first time at 1 year. Spawns in May – June. Females may spawn several times during a season. Adhesive eggs are deposited under or between stones, shells and aquatic plants. Males guard eggs until hatching. Males produce sounds when spawning and defending the nest. Feeds on a wide variety of benthic invertebrates.
Conservation status. VU B2ab (ii,iii,iv,v). Threatened by habitat destruction, pollution and possibly competition with introduced *P. bonelli*.
Remarks. Morphological and molecular data suggest that *P. nigricans* represents a distinct genus.
Further reading. Gandolfi & Tongiorgi, 1974 (description, biology); Pirisinu & Natali, 1980 (description, biology); Miller, 1990 (biology), 2004: 56 (biology); Penzo et al., 1998 (genetics).

Key to species of *Pomatoschistus* entering freshwater in Europe

The genus *Pomatoschistus* includes 12 species, all in Europe; most are purely marine or enter estuaries and coastal lagoons and only *P.* sp. Skadar is a strict freshwater inhabitant. *P. microps* and *P. canestrinii* regularly enter freshwater; in addition, *P. canestrinii* has also been introduced in freshwater lakes. Four additional species are occasionally recorded to enter brackish waters of estuaries and coastal lagoons and might accidentally find their way into freshwater. These species can be distinguished using the key below.
Further reading. Miller, in Whitehead et al., 1986: 1067 (identification of marine and brackish water species).

1a – Body without scales or scales only under pectoral; caudal peduncle naked. ..... *P.* sp. Skadar
1b – Flank and caudal peduncle covered by scales. 2

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2a – 55–75 total scales in midlateral series; predorsal area and nape covered by scales. ..... *P. minutus*

2b – 29–52 total scales in midlateral series; predorsal area and nape naked. 3

3a – Small black spots on body in males. ..... *P. canestrinii*

3b – Body without small black spots. 4

4a – Breast usually scaled; rear edge of anterior pelvic membrane with minute projections. ..... *P. marmoratus*

4b – Breast naked; rear edge of anterior pelvic membrane without projections. 5

5a – 39–52 total scales in midlateral series; in males, first dorsal with conspicuous dark posterior spot. ..... *P. microps*

6b – 30–38 total scales in midlateral series; in males, first dorsal without conspicuous dark posterior spot. 6

7a – 14–16 pectoral rays; male with several short bars on flank, mostly on lower half; female with 3–4 short bars on flank, mostly on lower half (Mediterranean). ..... *P. bathi*

6b – 17–20 pectoral rays; male with numerous indistinct bars on flank; female with 3 bars posteriorly on flank (Sicily, Libya). ..... *P. tortonesei*

Pomatoschistus canestrinii

Common name. Black-spot goby.

Diagnosis. Distinguished from other Gobiidae in freshwaters of Adriatic basin and western Italy by: ● small, black spots on body in males / ○ cephalic lateral line canals present (Fig. 92a) / ○ anterior oculoscapular canal extending to snout (Fig. 92a) / ○ 8–9½ branched rays in second dorsal / ○ anal origin below simple or first branched ray of second dorsal / ○ 36–42 total scales in midlateral series / ○ caudal peduncle completely scaled. Size up to 67 mm SL

Distribution. Adriatic coasts, from Po delta (Italy) to Neretva (Croatia). Introduced in Lake Trasimeno, Central Italy.

Habitat. Inshore habitats, estuaries, brackish- and fresh-water lagoons, lakes and large to medium size rivers, on sand or mud bottom. Found mainly on open sand or mud bottom.

Biology. Spawns after first winter in March – July. Individual females spawn several times during a season. Adhesive eggs are deposited under or between stones, shells and aquatic plants. Males guard eggs until hatching. Feeds on a wide variety of benthic invertebrates.

Conservation status. LC.

Remarks. In freshwater populations of Croatia, there is a tendency to reduction of squamation and cephalic canals.

Further reading. Gandolfi et al., 1982 (biology);

Pomatoschistus canestrinii

Pomatoschistus microps

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Pomatoschistus canestrinii; Ricica, Croatia; male, 30 mm SL.

Pomatoschistus canestrinii; Istria, Croatia; ~55 mm SL. A. Hartl

Pomatoschistus microps; Baltic coast, Germany; ~25 mm SL.

Freyhof, 1998 (introduction); Miller, 2004: 284 (description, biology); Kovačić, 2005b (morphology).

Pomatoschistus microps

Common name. Common goby.

Diagnosis. Distinguished from other species of Gobiidae in European freshwaters by: ○ cephalic lateral line canals present (Fig. 92a) / ○ anterior oculoscapular canal extending to snout / ○ 8–10½ branched rays in second dorsal / ○ anal origin below simple or first branched ray of second dorsal / ○ 39–52 total scales in midlateral series / ○ postdorsal body completely scaled / ○ predorsal area and nape naked / ○ caudal rounded / ○ males with conspicuous dark proximal posterior spot on first dorsal / ○ 17–19 pectoral rays. Size up to 55 mm SL.

Distribution. Coastal waters of Atlantic from northern Morocco northward to southern Norway, Baltic northward to about 63°N; isolated records from northwestern Mediterranean.

Habitat. Inshore, estuaries, brackish- and freshwater lagoons and lakes connected to sea, large to medium size rivers. Usually found on sand or mud.

Biology. Lives up to 2 years. Spawns after first

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Pomatoschistus sp. Skadar; Moraca, Drin drainage, Montenegro; male, ~28 mm SL.

winter. Spawns at sea in February – September, depending on latitude. Individual females spawn several times during a season. Adhesive eggs, 0.9 × 0.7 mm, are deposited under or between stones, shells and aquatic plants. Males guard eggs until hatching. Juveniles enter freshwater habitats in late summer to forage. Feeds on a wide variety of benthic invertebrates.

Conservation status. LC.

Further reading. Miller, 2004: 293 (description, biology).

Pomatoschistus sp. Skadar

Common name. Skadar goby.

Diagnosis. Distinguished from other Gobiidae in freshwaters of Adriatic basin and western Italy by: ● body without scales or scales only under pectoral / ● caudal peduncle naked / ○ small black spots on body in males / ○ anterior oculoscapular canal absent or extending to interorbital space / ○ 8–9½ branched rays in second dorsal / ○ anal origin below simple or first branched ray of second dorsal. Size up to 67 mm SL.

Distribution. Lake Skadar basin (Montenegro).

Habitat. Lakes and large to medium size rivers, mainly on on sand or mud bottom.

Biology. Spawns after first winter in March – July. Individual females spawn several times during a season. Adhesive eggs are deposited under or between stones, shells and aquatic plants. Males guard eggs until hatching. Feeds on a wide variety of benthic invertebrates.

Conservation status. LC*.

Further reading. Stelbrink & Freyhof, 2006: 71 (morphology; as *P. canestrinii*).

Key to species of *Proterorhinus*

All freshwater species of *Proterorhinus* have long been confused under the name *P. marmoratus*. Morphological and molecular data show that the real *P. marmoratus* does not enter pure freshwaters; it inhabits brackish waters in Sevastopol, Crimea, and therefore is only mentioned in the key. Preliminary observations suggest that other brackish water *Proterorhinus* may represent additional species.

1a – Head length 28–31 % SL; 13–16 rays in anal. 2

1b – Head length 24–28 % SL; 15–17 rays in anal (Crimea). 3

2a – Eye diameter 20–28 % HL. ..... *P. semilunaris*

2b – Eye diameter 16–21 % HL. ..... *P. nasalis*

3a – Total scales in midlateral series 43–45; interorbital distance 10–15 % HL (marine). ..... *P. marmoratus*

3b – Total scales in midlateral series 47–54; interorbital distance 16–20 % HL. ..... *P. tataricus*

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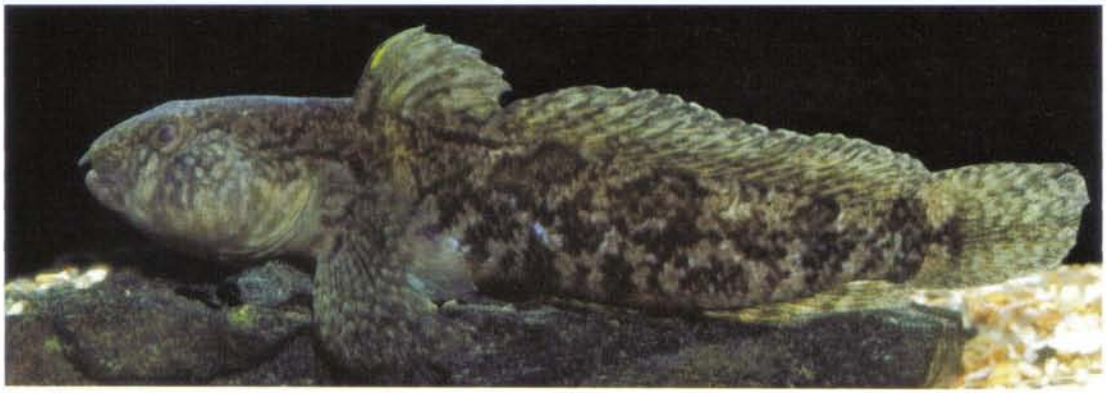

Proterorhinus marmoratus; Sevastopol, Ukraine; male, 61 mm SL.

Proterorhinus marmoratus; Sevastopol, Ukraine; female, ~50 mm SL.

Proterorhinus nasalis

Common name. Eastern tubenose goby.

Diagnosis. Distinguished from other species of *Proterorhinus* by: ♦ head length 29–31 % SL / ♦ eye diameter 16–21 % HL / ♦ 14–16 rays in anal / ♦ total scales in midlateral series 43–49. Size up to 90 mm SL.

Distribution. Azov and Caspian Sea basins. In Volga, native in delta, now reaching up to Lake Rybinskoye. *Proterorhinus* opulations from the western Caucasus coast in Russia and Georgia most likely belong to this species.

Habitat. A variety of slow-flowing or still waters. Usually associated with dense vegetation or coarse rocks.

Biology. Spawns for the first time at 1–2 years. Usually spawns only 1–2 seasons, in April – August. Females spawn more than once during a season. Males guard the eggs, which are deposited in cavities. Larvae and juveniles benthic. Feeds on benthic invertebrates.

Conservation status. LC. Invasive in Volga where its spreading is reportedly facilitated by canalization of main river and reservoirs or slow-flowing waters created by hydroelectric plants.

Further reading. Miller, 2004: 70 (description, biology); Naseka et al., 2005 (invasion).

Pomatoschistus sp. Skadar

Proterorhinus nasalis

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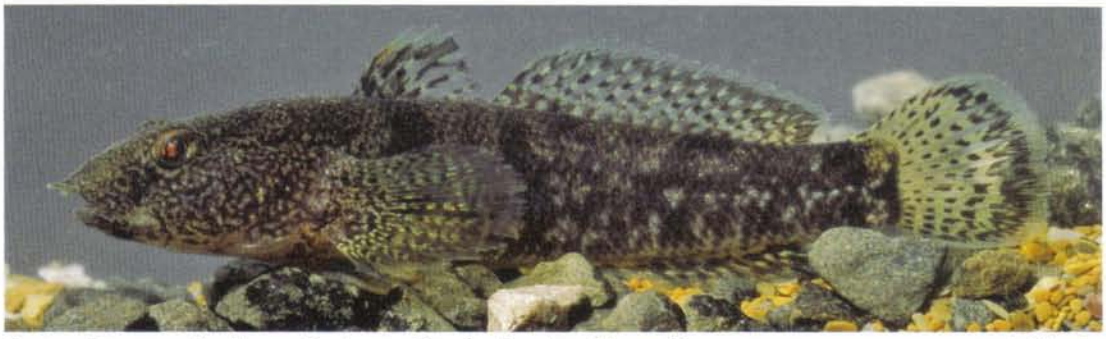
Proterorhinus nasalis; Samur, Daghestan, Russia; male, ~65 mm SL. A. Naseka



Proterorhinus nasalis; Samur, Daghestan, Russia; female, ~50 mm SL. A. Naseka

Proterorhinus semilunaris

Common name. Western tubenose goby.

Diagnosis. Distinguished from other species of *Proterorhinus* by: ○ head length 28–31 % SL / ○ eye diameter 20–28 % HL / ○ 13–15, rarely 16, rays in anal / ○ total scales in midlateral series 41–47. Size up to 90 mm SL.

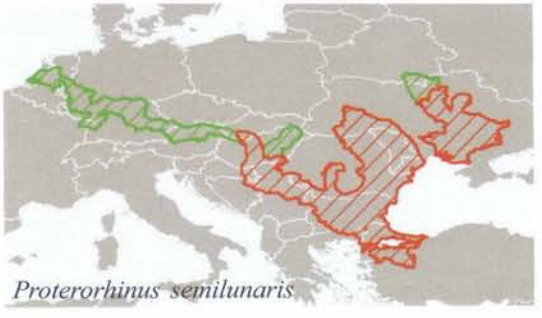
Distribution. Black Sea basin; Maritza and Struma drainages in eastern Aegean basin. In Danube, historically present up to about Vienna, invasive since 1970s, now reaching upstream to southern Germany. Recorded in 1999 from Rhine where it arrived from Danube through a canal and spread as far as the Netherlands (2002). In South Bug and Dniepr native far upriver. Arrived in North America in ballast of ships in 1991.

Habitat. A variety of slow-flowing or still waters from estuarine to small, slowly flowing premontane streams. Usually associated with dense vegetation or coarse rocks. Often very abundant in backwaters and lakes, proliferates in reservoirs and channels.

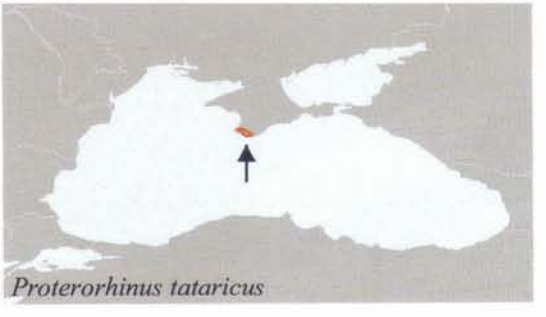
Biology. Spawns for the first time at 1–2 years. Usually spawns only 1–2 seasons, in April – August. Females spawn more than once during a season. Males guard the eggs, which are deposited in cavities. Larvae and juveniles benthic. Feeds on benthic invertebrates.

Conservation status. LC. Not threatened. Invasive in Danube and Rhine where its spreading is reportedly facilitated by canalization of main river and reservoirs or slow-flowing waters created by hydroelectric plants.

Further reading. Ahnelt et al., 1998 (invasion);



Proterorhinus semilunaris



Proterorhinus tataricus

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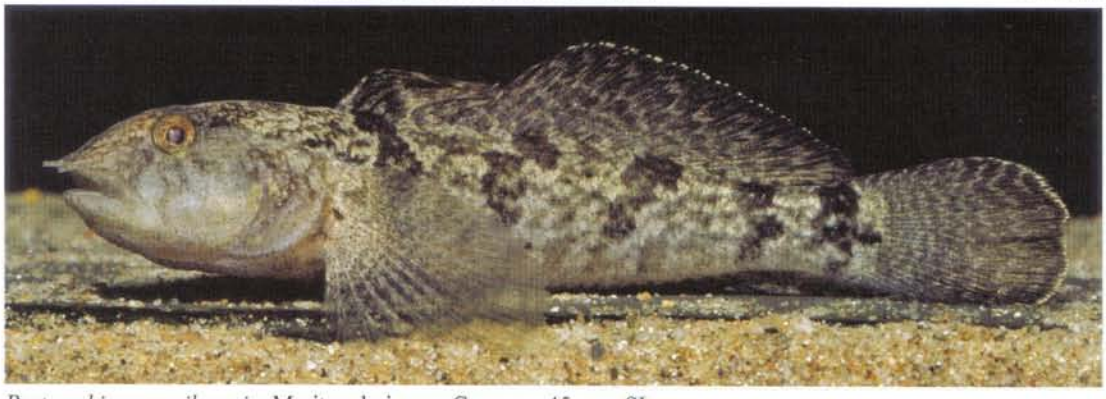
Proterorhinus semilunaris; Danube, Germany; 60 mm SL mm SL. A. Hartl



Proterorhinus semilunaris; Maritza drainage, Greece; ~45 mm SL.

Proterorhinus tataricus; Chornaya, Crimea, Ukraine; ~70 mm SL.

Naseka et al., 2005 (invasion); Miller, 2004: 70 (description, biology); Stepien & Tumeo, 2006 (genetics).

Proterorhinus tataricus

Common name. Chornaya tubenose goby.

Diagnosis. Distinguished from other species of *Proterorhinus* by: ♦ total scales in midlateral series 47–54 / ♦ interorbital distance 16–20 % HL / ♦ head length 25–28 % SL / ♦ 15–17 rays in anal. Size up to about 70 mm SL.

Distribution. Chornaya drainage (southern Crimea, Ukraine).

Habitat. A wide variety of habitats. Chornaya is a medium-sized stream with a flow of about 10 m^3/s. The inhabited stretch is about 25 km long. In its lower part, water is extracted in large quantities for irrigation and the stream is almost dry in summer.

Biology. No data.

Conservation status. CR B1ab(ii,iii) + 2ab (ii,iii). Still abundant in a very limited stretch of stream, but declining. If water abstraction intensifies, the whole steam might dry in summer.

Further reading. Freyhof & Naseka, 2007 (description).

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Family Pleuronectidae

Righteye flounders

Flatfishes are an unique group of mainly marine fishes easily distinguished by having both eyes on the same side of the laterally very compressed body. They are known to have remained almost unchanged since the Eocene (34–56 million years ago). Recent species of flatfishes are divided into 12 families, of which only the Pleuronectidae enter European freshwaters. Several other species (e.g. *Citharus* [family Citharidae], *Solea* [family Soleidae], *Scophthalmus* [family Scophthalmidae]) may occasionally be found in estuaries, especially during high tides..

Three species of flatfishes enter freshwater habitats in Europe and are included here. *Citharus linguatulus* enters brackish waters of large estuaries and might be found in saline coastal lagoons. It is known from the Mediterranean, eastern Atlantic coast of Spain, Portugal and Africa south to Angola. There is a record of a single individual collected in Lake Skadar (Montenegro).

As presently recognized, the family Pleuronectidae includes 28 genera and about 70 species found in all seas of the world. Systematics and generic positions of European species is still under debate.

Further reading. Ivanovic, 1973: 124 (Skadar *C. linguatulus*); Whitehead et al., 1986 (identification European marine species); Cooper & Chapleau, 1998 (phylogeny); Evseenko, 2004 (checklist).

Key to species of flatfishes recorded from European freshwaters

1a – Mouth large, posterior extremity of upper jaw reaching posterior margin of eye, length of upper jaw about 2 times in head length; anteriorly, lateral line strongly curved towards dorsum; eyes on left side; 63–71½ dorsal rays; 43–47½ anal rays.
..... *Citharus linguatulus*

1b – Mouth small, posterior extremity of upper jaw reaching anterior margin of eye, length of upper jaw about 4–5 times in head length; lateral line almost straight; eyes on right side (often on left side in *P. flesus*); 49–78½ dorsal rays; 33–66½ anal rays.
..... 2

2a – Enlarged scales along dorsal and anal bases; bony tubercles along lateral line.
..... *Platichthys flesus*

2b – Scales along dorsal and anal bases not larger than those on rest of body; no bony tubercles along lateral line.
..... 3

3a – No bony tubercles behind eyes; 52–59 total lateral line scales; 49–59½ dorsal rays; 34–43½ anal rays.
..... *Liopsetta glacialis*

3b – 4–7 bony tubercles behind eyes; 88–115 total lateral line scales; 64–78½ dorsal rays, 47–58½ anal rays.
..... *Pleuronectes platessa*

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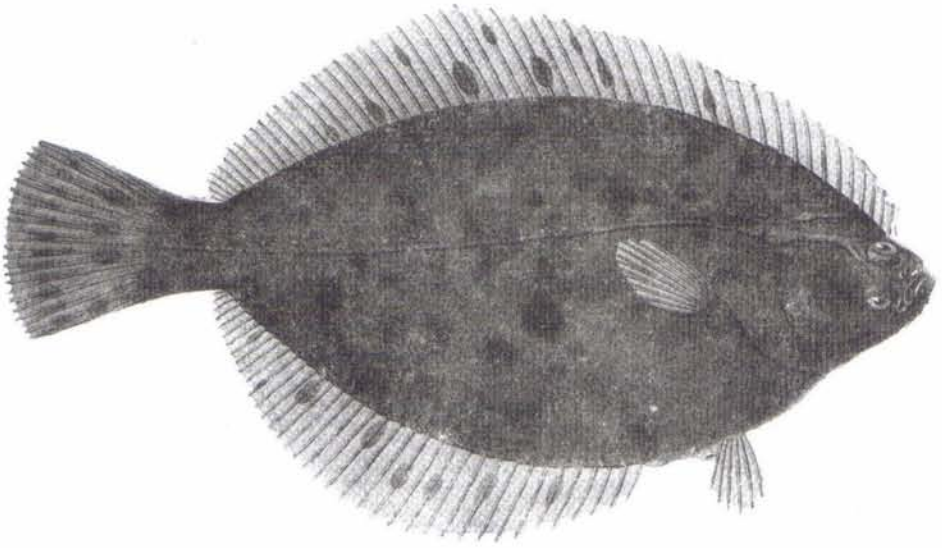


Liopsetta glacialis; White Sea, Russia; 234 mm SL. (from Berg, 1932)

Liopsetta glacialis

Common name. Arctic flounder.

Diagnosis. Distinguished from other species of flatfishes in freshwater in Europe by: ○ 52–59 total lateral line scales / ○ scales along dorsal and anal bases not larger than those on rest of body / ○ no bony tubercles along lateral line / ○ 49–59½ dorsal rays / ○ 34–43½ anal rays / ○ eyes on right side. Size up to 260 mm SL.

Distribution. Circumpolar. In Europe: eastern Atlantic, White and Barents Seas.

Habitat. Mud and sand bottom in shallow water, at sea and in estuaries, frequently entering freshwaters.

Biology. Spawns in December – May under ice. Spawning in May reported from White Sea. Feeds on small fishes and benthic invertebrates.

Conservation status. LC.

Further reading. Sakamoto, 1984 (systematics); Voronina & Evseenko, 2001 (systematics).

Platichthys flesus

Common name. Flounder.

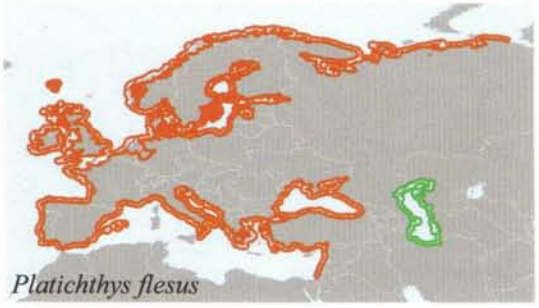
Diagnosis. Distinguished from other species of flatfishes entering European freshwaters by: ○ about 80 total lateral line scales / ○ enlarged scales along dorsal and anal bases / ● bony tubercles along lateral line / ○ 51–66½ dorsal rays / ○ 35–45½ anal rays / ○ eyes on right side (but, in North Sea, up to 40 % of individuals may have eyes on left side). Size up to 500 mm SL.

Distribution. Eastern Atlantic, from White to Mediterranean and Black Seas. Introduced in Caspian Sea and Great Lakes of North America. Enters rivers and coastal streams. In Rhine, occasionally recorded up to 650 km upriver.

Habitat. Mud and sand bottom in shallow water, at sea and in estuaries, frequently entering freshwaters.

Biology. Males reproduce for the first time at 2–3 years, females at 3–4. Migrates to sea in October – December. Spawns at sea, in deepwater, in January – June. Eggs and larvae are pelagic and drift

Liopsetta glacialis



Platichthys flesus

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Platichthys flesus; Belbek, Ukraine; 106 mm SL.

Pleuronectes platessa; Baltic Sea, Germany; ~300 mm SL. V. Huckstorf

with current. At about 10 mm SL, left eye moves to right side, pigmentation develops, and juveniles switch to benthic life. Pelagic larvae migrate to brackish- and fresh-water habitats with tidal currents; they move in the water column during flood and to the bottom during ebb. First pelagic flounders are usually recorded in estuaries in March. Juveniles start to migrate upriver to forage by mid-April. Not all individuals enter brackish- and freshwater. Spawned adults do not return to brackish

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or freshwater but remain at sea. Feeds on small fishes and benthic invertebrates.
Conservation status. LC.
Remarks. In need of critical taxonomic revision; several species seem to be confused under the name *P. flesus*.
Further reading. Voronina, 1999 (systematics).

Pleuronectes platessa

Common name. Plaice.
Diagnosis. Distinguished from other species of flatfishes in European freshwaters by: ● 4–7 bony tubercles behind eyes / ○ 64–78½ dorsal rays / ○ 47–58½ anal rays / ○ eyes on right side / ○ 88–115 total lateral line scales / ○ scales along dorsal and anal bases not larger than those on rest of body / ○ no bony tubercles along lateral line. Size up to 1000 mm SL.
Distribution. Western Mediterranean and along all European coasts to White and Barents Seas; absent from northern Baltic, Black and Caspian Seas. Regularly reported from freshwaters in Kanin Peninsula (Barents Sea). Occasionally reported from freshwater outside Barents Sea basin, but individuals might be misidentified *P. flesus*.
Habitat. Mud and sand bottom from a few metres down to about 100 m, at sea and in estuaries, rarely entering freshwaters.
Biology. Males reproduce for the first time at 2–3 years, females at 3–4. Spawns at sea, in January – June, in deep water, at temperatures around 6°C. Eggs and larvae are pelagic and drift with current. At about 10 mm SL, left eye moves to right side, pigmentation develops, and juveniles switch to benthic life. Juveniles enter freshwater to forage in mid-June in Kanin Peninsula, remaining there until August. Not all individual enter brackish and fresh-water. Adults do not move into brackish or fresh water. Feeds on thin-shelled molluscs and polychaets.
Conservation status. LC.
Further reading. Sakamoto, 1984 (systematics).

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Appendix

List of European freshwater fishes with their nomenclatural author(s) and year of publication. The presence or absence of parentheses or squared brackets is not an inconsistency but obeys precise conditions of the International Code of Zoological Nomenclature; see p. 22 for explanations. An asterisk (*) indicates species not native to European waters.

The citation of nomenclatural authors is not required by the International Code of Zoological Nomenclature and in fact is not justified and better avoided in non-taxonomic publications, even if only to make the text more user-friendly and to avoid confusion with cited references. It is needed only in publications dealing with taxonomic and nomenclatural topics, for purposes of clarity.

Family Petromyzonidae
- *Caspiomyzon wagneri* (Kessler, 1870)
- *Eudontomyzon danfordi* Regan, 1911
- *Eudontomyzon hellenicus* Vladykov, Renaud, Kott & Economidis, 1982
- *Eudontomyzon mariae* (Berg, 1931)
- *Eudontomyzon stankokaramani* Karaman, 1974
- *Eudontomyzon vladykovi* Oliva & Zanandrea, 1959
- *Eudontomyzon* sp. migratory
- *Lampetra fluviatilis* (Linnaeus, 1758)
- *Lampetra planeri* (Bloch, 1784)
- *Lampetra zanandreai* Vladykov, 1955
- *Lethenteron camtschaticum* (Tilesius, 1811)
- *Lethenteron reissneri* (Dybowski, 1869)
- *Petromyzon marinus* Linnaeus, 1758

Family Acipenseridae
- **Acipenser baerii* Brandt, 1869
- *Acipenser colchicus* Marty, 1940
- *Acipenser gueldenstaedtii* Brandt & Ratzeburg, 1833
- *Acipenser naccarii* Bonaparte, 1836
- *Acipenser nudiventris* Lovetsky, 1828
- *Acipenser oxyrinchus* Mitchill, 1815
- *Acipenser persicus* Borodin, 1897
- *Acipenser ruthenus* Linnaeus, 1758
- *Acipenser stellatus* Pallas, 1771
- *Acipenser sturio* Linnaeus, 1758
- *Huso huso* (Linnaeus, 1758)

Family Anguillidae
- *Anguilla anguilla* (Linnaeus, 1758)

Family Clupeidae
- *Alosa agone* (Scopoli, 1786)
- *Alosa algeriensis* Regan, 1916
- *Alosa alosa* (Linnaeus, 1758)
- *Alosa caspia* Eichwald, 1838
- *Alosa fallax* (La Cepède, 1803)
- *Alosa immaculata* Bennett, 1835
- *Alosa kessleri* (Grimm, 1887)
- *Alosa killarnensis* Regan, 1916
- *Alosa macedonica* (Vinciguerra, 1921)
- *Alosa maeotica* (Grimm, 1901)
- *Alosa tanaica* (Grimm, 1901)
- *Alosa vistonica* Economidis & Sinis, 1986
- *Alosa volgensis* (Berg, 1913)
- *Alosa* sp. Skadar
- *Clupeonella abrau* (Maljatskij, 1928)
- *Clupeonella caspia* (Svetovidov, 1941)
- *Clupeonella cultriventris* (Nordmann, 1840)
- *Clupeonella tscharchalensis* (Borodin, 1896)

Family Cyprinidae
Subfamily Acheilognathinae
- *Rhodeus amarus* (Bloch, 1782)
- *Rhodeus meridionalis* Karaman, 1924

Subfamily Gobioninae
- *Gobio alverniae* Kottelat & Persat, 2005
- *Gobio brevicirris* Fowler, 1976
- *Gobio bulgaricus* Drensky, 1926
- *Gobio carpathicus* Vladykov, 1925
- *Gobio delyamurei* Freyhof & Naseka, 2005
- *Gobio feraeensis* Stephanidis, 1973
- *Gobio gobio* (Linnaeus, 1758)
- *Gobio holurus* Fowler, 1976
- *Gobio kovatschevi* Chichkoff, 1937
- *Gobio krymensis* Bănărescu & Nalbant, 1973
- *Gobio kubanicus* Vasilieva, in Vasilieva, Vasiliev & Kuga, 2004
- *Gobio lozanoi* Doadrio & Madeira, 2004
- *Gobio obtusirostris* Valenciennes, 1842
- *Gobio occitaniae* Kottelat & Persat, 2005
- *Gobio ohridanus* Karaman, 1924

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Gobio sarmaticus Berg, 1949
Gobio skadarensis Karaman, 1936
**Pseudorasbora parva* (Temminck & Schlegel, 1846)
Romanogobio albipinnatus (Lukasch, 1933)
Romanogobio antipai (Bănărescu, 1953)
Romanogobio belingi (Slastenenko, 1934)
Romanogobio benacensis (Pollini, 1816)
Romanogobio ciscaucasicus (Berg, 1932)
Romanogobio elimeius (Kattoulas, Stephanidis & Economidis, 1973)
Romanogobio kesslerii (Dybowski, 1862)
Romanogobio parvus Naseka & Freyhof, 2004
Romanogobio pentatrichus (Naseka & Bogutskaya, 1998)
Romanogobio tanaiticus (Naseka, 2001)
Romanogobio uranoscopus (Agassiz, 1828)
Romanogobio vladykovi (Fang, 1943)

Subfamily Cyprininae
Aulopyge huegelii Heckel, 1842
Barbus balcanicus Kotlík, Tsigenopoulos, Ráb & Berrebi, 2002
Barbus barbus (Linnaeus, 1758)
Barbus bergi Chichkoff, 1935
Barbus caninus Bonaparte, 1839
Barbus carpathicus Kotlík, Tsigenopoulos, Ráb & Berrebi, 2002
Barbus ciscaucasicus Kessler, 1877
Barbus cyclolepis Heckel, 1837
Barbus euboicus Stephanidis, 1950
Barbus haasi Mertens, 1924
Barbus kubanicus Berg, 1913
Barbus macedonicus Karaman, 1928
Barbus meridionalis Risso, 1827
Barbus peloponnesius Valenciennes, 1842
Barbus pergamonensis Karaman, 1971
Barbus petenyi Heckel, 1852
Barbus plebejus Bonaparte, 1839
Barbus prespensis Karaman, 1924
Barbus rebeli Koller, 1926
Barbus sperchiensis Stephanidis, 1950
Barbus strumicae Karaman, 1955
Barbus tauricus Kessler, 1877
Barbus tyberinus Bonaparte, 1839
Barbus waleckii Rolik, 1970
**Carassius auratus* (Linnaeus, 1758)
Carassius carassius (Linnaeus, 1758)
Carassius gibelio (Bloch, 1782)
Cyprinus carpio Linnaeus, 1758
Luciobarbus albanicus (Steindachner, 1870)
Luciobarbus bocagei (Steindachner, 1865)
Luciobarbus brachycephalus (Kessler, 1872)
Luciobarbus capito (Güldenstaedt, 1778)
Luciobarbus comizo (Steindachner, 1865)
Luciobarbus graecus (Steindachner, 1896)
Luciobarbus graellsii (Steindachner, 1866)
Luciobarbus guiraonis (Steindachner, 1866)
Luciobarbus microcephalus (Almaça, 1967)
Luciobarbus sclateri (Günther, 1868)
Luciobarbus steindachneri (Almaça, 1967)

Subfamily Leuciscinae
Abramis brama (Linnaeus, 1758)
Achondrostoma arcasii (Steindachner, 1866)
Achondrostoma occidentale (Robalo, Almada, Sousa Santos, Moreira & Doadrio, 2005)
Achondrostoma oligolepis (Robalo, Doadrio, Almada & Kottelat, 2005)
Alburnoides bipunctatus (Bloch, 1782)
Alburnoides ohridanus (Karaman, 1928)
Alburnoides prespensis (Karaman, 1924)
Alburnus albidus (Costa, 1838)
Alburnus alburnus (Linnaeus, 1758)
Alburnus arborella (Bonaparte, 1841)
Alburnus belvica Karaman, 1924
Alburnus chalcoides (Gueldenstaedt, 1772)
Alburnus danubicus Antipa, 1909
Alburnus hohenackeri Kessler, 1877
Alburnus istanbulensis Battalgil, 1941
Alburnus leobergi Freyhof & Kottelat, 2007
Alburnus macedonicus Karaman, 1928
Alburnus mandrensis Drensky, 1943
Alburnus mento (Heckel, 1836)
Alburnus mentoides Kessler, 1858
Alburnus sarmaticus Kottelat & Freyhof, 2007
Alburnus schischkovi Drensky, 1943
Alburnus scoranza Bonaparte, 1845
Alburnus thessalicus Stephanidis, 1950
Alburnus vistonicus Freyhof & Kottelat, 2007
Alburnus volviticus Freyhof & Kottelat, 2007
Alburnus sp. Volvi
Anaecypris hispanica (Steindachner, 1866)
Aspius aspius (Linnaeus, 1758)
Ballerus ballerus (Linnaeus, 1758)
Ballerus sapa (Pallas, 1814)
Blicca bjoerkna (Linnaeus, 1758)
Chondrostoma knerii Heckel, 1843
Chondrostoma kubanicum Berg, 1914
Chondrostoma nasus (Linnaeus, 1758)
Chondrostoma oxyrhynchum Kessler, 1877
Chondrostoma phoxinus Heckel, 1843
Chondrostoma prespense Karaman, 1924
Chondrostoma scodrense Elvira, 1987
Chondrostoma soetta Bonaparte, 1840
Chondrostoma vardarense Karaman, 1928
Chondrostoma variabile Yakovlev, 1870
Delminichthys adspersus (Heckel, 1843)
Delminichthys ghetaldii (Steindachner, 1882)
Delminichthys jadovensis (Zupančič & Bogutskaya, 2002)
Delminichthys krbavensis (Zupančič & Bogutskaya, 2002)
**Hypophthalmichthys molitrix* (Valenciennes, 1844)
**Hypophthalmichthys nobilis* (Richardson, 1845)
Iberochondrostoma almacai (Coelho, Mesquita & Collares-Pereira, 2005)
Iberochondrostoma lemmingii (Steindachner, 1866)
Iberochondrostoma lusitanicum (Collares-Pereira, 1980)
Iberochondrostoma oretanum (Doadrio & Carmona, 2003)
Iberocypris alburnoides (Steindachner, 1866)
Iberocypris palaciosi Doadrio, 1980
Ladigesocypris ghigii (Gianferrari, 1927)
Leucaspius delineatus (Heckel, 1843)
Leuciscus bearnensis (Blanchard, 1865)
Leuciscus burdigalensis Valenciennes, 1844

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Leuciscus danilewskii (Kessler, 1877)
Leuciscus idus (Linnaeus, 1758)
Leuciscus leuciscus (Linnaeus, 1758)
Leuciscus oxyrrhis La Blanchère, 1873
Pachychilon macedonicum (Steindachner, 1892)
Pachychilon pictum (Heckel & Kner, 1858)
Parachondrostoma arrigonis (Steindachner, 1866)
Parachondrostoma miegii (Steindachner, 1866)
Parachondrostoma toxostoma (Vallot, 1837)
Parachondrostoma turiense (Elvira, 1987)
Pelasgus epiroticus (Steindachner, 1896)
Pelasgus laconicus (Kottelat & Barbieri, 2004)
Pelasgus marathonicus (Vinciguerra, 1921)
Pelasgus minutus (Karaman, 1924)
Pelasgus prespensis (Karaman, 1924)
Pelasgus stymphalicus (Valenciennes, 1844)
Pelasgus thesproticus (Stephanidis, 1939)
Pelecus cultratus (Linnaeus, 1758)
Petroleuciscus borysthenicus (Kessler, 1859)
Petroleuciscus smyrnaeus (Boulenger, 1896)
Phoxinellus alepidotus Heckel, 1843
Phoxinellus dalmaticus Zupančič & Bogutskaya, 2000
Phoxinellus pseudalepidotus Bogutskaya & Zupančič, 2003
Phoxinus bigerri Kottelat, 2007
Phoxinus colchicus Berg, 1910
Phoxinus lumaireul Schinz, 1840
Phoxinus phoxinus (Linnaeus, 1758)
Phoxinus septimaniae Kottelat, 2007
Phoxinus strandjae Drensky, 1926
Phoxinus strymonicus Kottelat, 2007
**Pimephales promelas* Rafinesque, 1820
Protochondrostoma genei (Bonaparte, 1839)
Pseudochondrostoma duriense (Coelho, 1985)
Pseudochondrostoma polylepis (Steindachner, 1865)
Pseudochondrostoma willkommii (Steindachner, 1866)
Rhynchocypris czekanowskii (Dybowski, 1869)
Rhynchocypris percnurus (Pallas, 1814)
Rutilus aula (Bonaparte, 1841)
Rutilus basak (Heckel, 1843)
Rutilus caspicus (Yakovlev, 1870)
Rutilus frisii (Nordmann, 1840)
Rutilus heckelii (Nordmann, 1840)
Rutilus karamani Fowler, 1977
Rutilus meidingeri (Heckel, 1851)
Rutilus ohridanus (Karaman, 1924)
Rutilus panosi Bogutskaya & Iliadou, 2006
Rutilus pigus (La Cepède, 1803)
Rutilus prespensis (Karaman, 1924)
Rutilus rubilio (Bonaparte, 1837)
Rutilus rutilus (Linnaeus, 1758)
Rutilus virgo (Heckel, 1852)
Rutilus ylikiensis Economidis, 1991
Rutilus sp. Sperchios
Scardinius acarnanicus Economidis, 1991
Scardinius dergle Heckel & Kner, 1858
Scardinius erythrophthalmus (Linnaeus, 1758)
Scardinius graecus Stephanidis, 1937
Scardinius hesperidicus Bonaparte, 1845
Scardinius knezevici Bianco & Kottelat, 2005
Scardinius plotizza Heckel & Kner, 1858
Scardinius racovitzai Müller, 1958
Scardinius scardafa (Bonaparte, 1837)
Squalius albus (Bonaparte, 1838)
Squalius aphipsi (Aleksandrov, 1927)
Squalius aradensis (Coelho, Bogutskaya, Rodrigues & Collares-Pereira, 1998)
Squalius carolitertii (Doadrio, 1988)
Squalius cephalus (Linnaeus, 1758)
Squalius cf. *cii* (Richardson, 1856)
Squalius illyricus Heckel & Kner, 1858
Squalius keadicus (Stephanidis, 1971)
Squalius laietanus Doadrio, Kottelat & Sostoa, 2007
Squalius lucumonis (Bianco, 1983)
Squalius malacitanus Doadrio & Carmona, 2006
Squalius microlepis Heckel, 1843
Squalius moreoticus (Stephanidis, 1971)
Squalius orpheus Kottelat & Economidis, 2006
Squalius pamvoticus (Stephanidis, 1939)
Squalius peloponensis (Valenciennes, 1844)
Squalius prespensis (Fowler, 1977)
Squalius pyrenaicus (Günther, 1868)
Squalius squalus (Bonaparte, 1837)
Squalius svallize Heckel & Kner, 1858
Squalius tenellus Heckel, 1843
Squalius torgalensis (Coelho, Bogutskaya, Rodrigues & Collares-Pereira, 1998)
Squalius valentinus Doadrio & Carmona, 2006
Squalius vardarensis Karaman, 1928
Squalius zrmanjae Karaman, 1928
Squalius sp. Aoos
Squalius sp. Evia
Squalius sp. Evinos
Telestes beoticus (Stephanidis, 1939)
Telestes croaticus (Steindachner, 1866)
Telestes fontinalis (Karaman, 1972)
Telestes metohiensis (Steindachner, 1901)
Telestes montenigrinus (Vuković, 1963)
Telestes muticellus (Bonaparte, 1837)
Telestes pleurobipunctatus (Stephanidis, 1939)
Telestes polylepis Steindachner, 1866
Telestes souffia (Risso, 1827)
Telestes turskyi (Heckel, 1843)
Telestes ukliva (Heckel, 1843)
Tropidophoxinellus hellenicus (Stephanidis, 1939)
Tropidophoxinellus spartiaticus (Schmidt-Ries, 1943)
Vimba melanops (Heckel, 1837)
Vimba vimba (Linnaeus, 1758)

Subfamily Squaliobarbinae
**Ctenopharyngodon idella* (Valenciennes, 1844)
**Mylopharyngodon piceus* (Richardson, 1846)

Subfamily Tincinae
Tinca tinca (Linnaeus, 1758)

Family Cobitidae
Cobitis arachthosensis Economidis & Nalbant, 1997
Cobitis bilineata Canestrini, 1866
Cobitis calderoni Băcescu, 1962
Cobitis dalmatina Karaman, 1928
Cobitis elongata Heckel & Kner, 1858
Cobitis elongatoides Băcescu & Maier, 1969

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Cobitis hellenica Economidis & Nalbant, 1997
Cobitis illyrica Freyhof & Stelbrink, 2007
Cobitis melanoleuca Nichols, 1925
Cobitis meridionalis Karaman, 1924
Cobitis narentana Karaman, 1928
Cobitis ohridana Karaman, 1928
Cobitis paludica (de Buen, 1930)
Cobitis pontica Vasilieva & Vasiliev, 2006
Cobitis puncticulata Erk'akan, Atalay-Ekmekçi & Nalbant, 1998
Cobitis punctilineata Economidis & Nalbant, 1997
Cobitis stephanidisi Economidis & Nalbant, 1997
Cobitis strumicae Karaman, 1955
Cobitis taenia Linnaeus, 1758
Cobitis tanaitica Băcescu & Maier, 1969
Cobitis taurica Vasilieva, Vasiliev, Janko, Ráb & Rábová, 2005
Cobitis trichonica Stephanidis, 1974
Cobitis vardarensis Karaman, 1928
Cobitis vettonica Doadrio & Perdices, 1997
Cobitis zanandreai Cavicchioli, 1965
**Misgurnus anguillicaudatus* (Cantor, 1842)
Misgurnus fossilis (Linnaeus, 1758)
Sabanejewia balcanica (Karaman, 1922)
Sabanejewia baltica Witkowski, 1994
Sabanejewia bulgarica (Drensky, 1928)
Sabanejewia caucasica (Berg, 1906)
Sabanejewia kubanica Vasilieva & Vasiliev, 1988
Sabanejewia larvata (De Filippi, 1859)
Sabanejewia romanica (Băcescu, 1943)
Sabanejewia vallachica Nalbant, 1957

Family Nemacheilidae
Barbatula barbatula (Linnaeus, 1758)
Barbatula quignardi (Băcescu-Mester, 1967)
Barbatula sturanyi (Steindachner, 1892)
Barbatula zetensis (Šorić, 2001)
Oxynoemacheilus bureschi (Drensky, 1928)
Oxynoemacheilus merga (Krynicki, 1840)
Oxynoemacheilus pindus (Economidis, 2005)
Oxynoemacheilus theophilii Stoumboudi, Kottelat & Barbieri, 2006

Family Ictaluridae
**Ameiurus melas* (Rafinesque, 1820)
**Ameiurus nebulosus* (Leseur, 1819)
**Ictalurus punctatus* (Rafinesque, 1818)

Family Siluridae
Silurus aristotelis Garman, 1890
Silurus glanis Linnaeus, 1758

Family Esocidae
Esox lucius Linnaeus, 1758

Family Umbridae
Umbra krameri Walbaum, 1792
**Umbra pygmaea* (De Kay, 1842)

Family Osmeridae
Hypomesus olidus (Pallas, 1814)
Osmerus dentex Steindachner & Kner, 1870
Osmerus eperlanus (Linnaeus, 1758)

Family Coregonidae
Coregonus albellus Fatio, 1890
Coregonus albula (Linnaeus, 1758)
Coregonus alpinus Fatio, 1885
Coregonus arenicolus Kottelat, 1997
Coregonus atterensis Kottelat, 1997
Coregonus austriacus Vogt, 1909
Coregonus autumnalis (Pallas, 1776)
Coregonus baerii Kessler, 1864
Coregonus bavaricus Hofer, 1909
Coregonus bezola Fatio, 1888
Coregonus candidus Goll, 1883
Coregonus clupeoides La Cepède, 1803
Coregonus confusus Fatio, 1885
Coregonus danneri Vogt, 1908
Coregonus duplex Fatio, 1890
Coregonus fatioi Kottelat, 1997
Coregonus fera Jurine, 1825
Coregonus fontanae Schulz & Freyhof, 2003
Coregonus gutturosus (Gmelin, 1818)
Coregonus heglingus Schinz, 1822
Coregonus hiemalis Jurine, 1825
Coregonus hoferi Berg, 1932
Coregonus holsatus Thienemann, 1916
Coregonus kiletz (Michailovski, 1904)
Coregonus ladogae Pravdin, Golubev & Belyaeva, 1938
Coregonus lavaretus (Linnaeus, 1758)
Coregonus lucinensis Thienemann, 1933
Coregonus lutokka Kottelat, Bogutskaya & Freyhof, 2005
Coregonus macrophthalmus Nüsslin, 1882
Coregonus maraena (Bloch, 1779)
Coregonus maraenoides Polyakov, 1874
Coregonus maxillaris Günther, 1866
Coregonus megalops Widegren, 1863
Coregonus muksun (Pallas, 1814)
Coregonus nasus (Pallas, 1776)
Coregonus nilssoni Valenciennes, 1848
Coregonus nobilis Haack, 1882
Coregonus oxyrinchus (Linnaeus, 1758)
Coregonus palaea Cuvier, 1829
Coregonus pallasii Valenciennes, 1848
Coregonus peled (Gmelin, 1789)
Coregonus pennantii Valenciennes, 1848
Coregonus pidschian (Gmelin, 1789)
Coregonus pollan Thompson, 1835
Coregonus renke (Paula Schrank, 1783)
Coregonus restrictus Fatio, 1885
Coregonus sardinella Valenciennes, 1848
Coregonus stigmaticus Regan, 1908
Coregonus suidteri Fatio, 1885
Coregonus trybomi Svärdson, 1979
Coregonus vandesius Richardson, 1836
Coregonus vessicus Drjagin, 1932
Coregonus wartmanni (Bloch, 1784)
Coregonus widegreni Malmgren, 1863
Coregonus zuerichensis Nüsslin, 1882
Coregonus zugensis Nüsslin, 1882
Coregonus sp. winter spawning Brienz
Stenodus leucichthys (Gueldenstaedt, 1772)
Stenodus nelma (Pallas, 1773)

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Family Salmonidae
Hucho hucho (Linnaeus, 1758)
Hucho taimen (Pallas, 1773)
**Oncorhynchus gorbuscha* (Walbaum, 1792)
**Oncorhynchus mykiss* (Walbaum, 1792)
Salmo aphelios Kottelat, 1997
Salmo balcanicus (Karaman, 1927)
Salmo carpio Linnaeus, 1758
Salmo cenerinus Chiereghini, 1847
Salmo cettii Rafinesque Schmaltz, 1810
Salmo ciscaucasicus Dorofeyeva, 1967
Salmo dentex Heckel, 1852
Salmo ezenami Berg, 1948
Salmo farioides (Karaman, 1938)
Salmo ferox Jardine, 1835
Salmo fibreni Zerunian & Gandolfi, 1990
Salmo labrax Pallas, 1814
Salmo letnica (Karaman, 1924)
Salmo lumi Poljakov, Filipi & Basho, 1958
Salmo macedonicus (Karaman, 1924)
Salmo marmoratus Cuvier, 1829
Salmo montenigrinus (Karaman, 1933)
Salmo nigripinnis Günther, 1866
Salmo obtusirostris (Heckel, 1852)
Salmo ohridanus Steindachner, 1892
Salmo pelagonicus Karaman, 1938
Salmo peristericus Karaman, 1938
Salmo rhodanensis Fowler, 1974
Salmo salar Linnaeus, 1758
Salmo '*schiefermuelleri*' Bloch, 1784
Salmo stomachicus Günther, 1866
Salmo taleri (Karaman, 1932)
Salmo trutta Linnaeus, 1758
Salmo sp. Louros
Salvelinus alpinus (Linnaeus, 1758)
Salvelinus colii (Günther, 1863)
Salvelinus evasus Freyhof & Kottelat, 2005
Salvelinus faroensis Joensen & Tåning, 1970
Salvelinus fimbriatus Regan, 1908
**Salvelinus fontinalis* (Mitchill, 1814)
Salvelinus gracillimus Regan, 1909
Salvelinus grayi (Günther, 1862)
Salvelinus inframundus Regan, 1909
Salvelinus killinensis (Günther, 1865)
Salvelinus lepechini (Gmelin, 1789)
Salvelinus lonsdalii Regan, 1909
Salvelinus mallochi Regan, 1909
Salvelinus maxillaris Regan, 1909
Salvelinus murta (Saemundsson, 1909)
**Salvelinus namaycush* (Walbaum, 1792)
Salvelinus neocomensis Freyhof & Kottelat, 2005
Salvelinus obtusus Regan, 1908
Salvelinus perisii (Günther, 1865)
Salvelinus profundus Schillinger, 1901
Salvelinus salvelinoinsularis (Lönnberg, 1900)
Salvelinus struanensis (Maitland, 1881)
Salvelinus thingvallensis (Saemundsson, 1909)
Salvelinus umbla (Linnaeus, 1758)
Salvelinus willoughbii (Günther, 1862)
Salvelinus youngeri Friend, 1956
Salvelinus sp. Båtsvatn
Salvelinus sp. Fjellfrøsvatn
Salvelinus sp. Loch Awe spring spawner
Salvelinus sp. Loch Maree large eye
Salvelinus sp. Loch Maree slender
Salvelinus sp. Rannoch benthivorous
Salvelinus sp. Rannoch piscivorous
Salvelinus sp. Thingvalla large benthivorous
Salvelinus sp. Windermere spring spawner

Family Thymallidae
Thymallus arcticus (Pallas, 1776)
Thymallus thymallus (Linnaeus, 1758)

Family Lotidae
Lota lota (Linnaeus, 1758)

Family Mugilidae
Chelon labrosus Risso, 1827
Liza aurata (Risso, 1810)
**Liza haematocheilus* (Temminck & Schlegel, 1845)
Liza ramada (Risso, 1827)
Liza saliens (Risso, 1810)
Mugil cephalus Linnaeus, 1758

Family Atherinidae
Atherina boyeri Risso, 1810

Family Atherinopsidae
**Odonthestes bonariensis* (Valenciennes, 1835)

Family Adrianichthyidae
**Oryzias sinensis* Chen, Uwa & Chu, 1989

Family Fundulidae
**Fundulus heteroclitus* (Linné, 1766)

Family Valenciidae
Valencia hispanica (Valenciennes, 1846)
Valencia letourneuxi (Sauvage, 1880)

Family Poeciliidae
**Gambusia holbrooki* Girard, 1859
**Poecilia reticulata* Peters, 1860

Family Cyprinodontidae
Aphanius almiriensis Kottelat, Barbieri & Stoumboudi, 2007
Aphanius baeticus Doadrio, Carmona & Fernández-Delgado, 2002
Aphanius fasciatus (Valenciennes, 1821)
Aphanius iberus (Valenciennes, 1846)

Family Gasterosteidae
**Culaea inconstans* (Kirtland, 1840)
Gasterosteus aculeatus Linnaeus, 1758
Gasterosteus crenobiontus Băcescu & Mayer, 1956
Gasterosteus gymnurus Cuvier, 1829
Gasterosteus islandicus Sauvage, 1874
Pungitius hellenicus Stephanidis, 1971
Pungitius laevis (Cuvier, 1829)
Pungitius platygaster (Kessler, 1859)
Pungitius pungitius (Linnaeus, 1758)

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Family Syngnathidae
Syngnathus abaster Risso, 1827

Family Cottidae
Cottus aturi Freyhof, Kottelat & Nolte, 2005
Cottus duranii Freyhof, Kottelat & Nolte, 2005
Cottus gobio Linnaeus, 1758
Cottus haemusi Marinov & Dikov, 1986
Cottus hispaniolensis Băcescu & Băcescu-Mester, 1964
Cottus koshewnikowi Gratzianov, 1907
Cottus metae Freyhof, Kottelat & Nolte, 2005
Cottus microstomus Heckel, 1837
Cottus perifretum Freyhof, Kottelat & Nolte, 2005
Cottus petiti Băcescu & Băcescu-Mester, 1964
Cottus poecilopus Heckel, 1837
Cottus rhenanus Freyhof, Kottelat & Nolte, 2005
Cottus rondeleti Freyhof, Kottelat & Nolte, 2005
Cottus scaturigo Freyhof, Kottelat & Nolte, 2005
Cottus transsilvaniae Freyhof, Kottelat & Nolte, 2005
Triglopsis quadricornis (Linnaeus, 1758)

Family Moronidae
Dicentrarchus labrax (Linnaeus, 1758)

Family Centrarchidae
**Ambloplites rupestris* (Rafinesque, 1817)
**Lepomis gibbosus* (Linnaeus, 1758)
**Micropterus salmoides* (La Cepède, 1802)

Family Percidae
Gymnocephalus acerina (Gueldenstaedt, 1774)
Gymnocephalus baloni Holčík & Hensel, 1974
Gymnocephalus cernua (Linnaeus, 1758)
Gymnocephalus schraetser (Linnaeus, 1758)
Perca fluviatilis Linnaeus, 1758
Percarina demidoffii Nordmann, 1840
Percarina maeotica Kuznetsov, 1888
Romanichthys valsanicola Dumitrescu, Bănărescu & Stoica, 1957
Sander lucioperca (Linnaeus, 1758)
Sander volgensis (Gmelin, 1789)
Zingel asper (Linnaeus, 1758)
Zingel balcanicus (Karaman, 1936)
Zingel streber (Siebold, 1863)
Zingel zingel (Linné, 1766)

Family Cichlidae
**Australoheros facetus* (Jenyns, 1842)
**Hemichromis fasciatus* Peters, 1858
**Hemichromis guttatus* Günther, 1862
**Herotilapia multipinosa* (Günther, 1867)
**Oreochromis niloticus* (Linnaeus, 1758)

Family Blenniidae
Salaria economidisi Kottelat, 2004
Salaria fluviatilis (Asso, 1801)

Family Odontobutidae
**Perccottus glenii* Dybowski, 1877

Family Gobiidae
Benthophiloides brauneri Beling & Iljin, 1927
Benthophilus durrelli Boldyrev & Bogutskaya, 2004
Benthophilus granulosus Kessler, 1877
Benthophilus leobergius Berg, 1949
Benthophilus macrocephalus (Pallas, 1787)
Benthophilus magistri Iljin, 1927
Benthophilus mahmudbejovi Ragimov, 1976
Benthophilus nudus Berg, 1898
Benthophilus stellatus (Sauvage, 1874)
Caspiosoma caspium (Kessler, 1877)
Economidichthys pygmaeus (Holly, 1929)
Economidichthys trichonis Economidis & Miller, 1990
Knipowitschia bergi (Iljin, 1928)
Knipowitschia cameliae Nalbant & Otel, 1996
Knipowitschia caucasica (Berg, 1916)
Knipowitschia croatica Mrakovčić, Kerovec, Mišetić & Schneider, 1994
Knipowitschia goerneri Ahnelt, 1991
Knipowitschia longecaudata (Kessler, 1877)
Knipowitschia milleri (Ahnelt & Bianco 1990)
Knipowitschia panizzae (Verga, 1841)
Knipowitschia punctatissima (Canestrini, 1864)
Knipowitschia radovici Kovačić, 2005
Knipowitschia thessala (Vinciguerra, 1921)
Knipowitschia sp. Visovac
Mesogobius batrachocephalus (Pallas, 1814)
Neogobius constructor (Nordmann, 1840)
Neogobius eurycephalus (Kessler, 1874)
Neogobius fluviatilis (Pallas, 1814)
Neogobius gorlap (Iljin, 1949)
Neogobius gymnotrachelus (Kessler, 1857)
Neogobius kessleri (Günther, 1861)
Neogobius melanostomus (Pallas, 1814)
Neogobius pallasi (Berg, 1916)
Neogobius syrman (Nordmann, 1840)
Padogobius bonelli (Bonaparte, 1846)
Padogobius nigricans (Canestrini, 1867)
Pomatoschistus canestrinii (Ninni, 1883)
Pomatoschistus microps (Krøyer, 1838)
Pomatoschistus sp. Skadar
Proterorhinus nasalis (Filippi, 1863)
Proterorhinus semilunaris (Heckel, 1837)
Proterorhinus tataricus Freyhof & Naseka, 2007

Family Pleuronectidae
Liopsetta glacialis (Pallas, 1776)
Platichthys flesus (Linnaeus, 1758)
Pleuronectes platessa Linnaeus, 1758

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Glossary

adnate: attached, united.

aff., affinis: [Latin] added between the genus and the species names indicates a species that cannot be identified with any known species or is probably new to science (but without formal scientific name). The use of 'aff.' is to ally it with what is possibly a closely related species. *See also:* cf., sp.

alevin: hatched fish with yolk-sack. The stage before the fry stage.

alien: a species not native to a given area and that has established a breeding population, resulting from introduction, escape or invasion.

allometry: the change in proportion of various parts of an organism with its overall growth.

allopatric: two or more species sharing some sort of evolutionary relationship and whose ranges are nowhere in contact. *See also:* parapatric, sympatric.

allotopic: two or more species sharing some sort of evolutionary relationship which, although their ranges overlap, do not occur together (usually because they occupy different habitats). *See also:* syntopic.

Alpine: of or related to the Alps. Here, of coregonids, the species of central Europe as opposed to the Nordic ones.

alpine: of or relating to high hill ranges.

ammocoete: a lamprey larva.

anadromous: those *species* that migrate between fresh and sea water to spawn in freshwaters (like the salmon *Salmo salar*).

aufwuchs: epilithic assemblage of variety of unicellular and filamentous green and blue-green algae growing directly on rocks, diatoms that grow on filamentous algae, moss animals (bryozoa), ciliates colonies and sponges. Associated insect larvae and microcrustaceans living between the algal filaments are often considered part of the aufwuchs.

axial streak: a dark line running along side, under the skin, along the confluence of the dorsal and ventral musculatures.

backwater: body of still water connected to a river, created by a flood or a tide.

band: an elongate colour mark that is neither a bar nor a stripe.

bar: a vertical colour mark.

base of fin: the area of attachment of a fin to the body.

benthic: living at the bottom.

bicuspid: with two cusps (points, for example, of a tooth; *see* Fig. 87b).

biodiversity: the measure of the relative diversity among organisms present in different ecosystems, including the diversity of durable interactions among species and ecological, meteorological and geomorphological processes.

The 'legal' definition adopted by the United Nations Convention on Biological Diversity (CBD) is: "The variability among living organisms from all sources, including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems". (The parties to the convention include all the countries on Earth with the exception of Andorra, Brunei Darussalam, the Holy See, Iraq, Somalia, Timor-Leste, and the United States of America.)

blotch: a variably shaped but not elongate pigmented mark, larger than the eye.

branchiostegal membrane: the paired membrane containing the branchiostegal rays, closing the lower part of the gill cavity and more or less fused with the skin of the throat.

branchiostegal rays: the elongate bones supporting the branchiostegal membrane, located below the opercle.

breast: the ventral surface of the body between the isthmus and the base of the pectoral fins.

breeding tubercle: *see* tubercles.

caecum (plural: caeca)**:** a fingerlike or pouchlike evagination of the gut.

canine: a large conical tooth in the anterior part of the mouth.

catadromous: those *species* that migrate between fresh and sea water to spawn in the sea (like the eel *Anguilla anguilla*).

caudal peduncle: the part of the body between

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the base of the last anal-fin ray and the base of the caudal fin.

cf., confer: [Latin] added between the genus and the species names indicates individuals, populations or a species quite similar to a known species but differing by some details and of which it can presently not be decided whether they are conspecific or not. *See also:* aff., sp.

character: any of the morphological, ethological, molecular and other features that may be used to diagnose a taxon.

character state: each of the alternative conditions which a given character may have; it is fixed in the species, and thus present in all individuals.

cheek: the side of the head below and behind the eye.

chin: the anterior part of the lower jaw.

circulus (plural: circuli)**:** the concentric rings on a scale.

clay: a soil category; very fined grained material, finer than silt.

cleithrum: the largest bone of the pectoral girdle, located immediately behind the gill opening.

cline: gradual geographic variation of one or more characters in the range of a species.

compressed: laterally flattened.

congeneric: species belonging to the same genus.

conspecific: individuals belonging to the same species.

crenated: having a margin with low, rounded or squarish projections.

crenulated: having a margin with small, rounded teeth

ctenii: minute spines along the posterior margin of ctenoid scales (*see* Fig. 9).

deciduous: falling off at some stage of maturity.

demersal: on or near the bottom.

depressed: flattened dorsoventrally, therefore broader than deep.

diadromous: those *species* that migrate between fresh and seawater at different periods of their life, either to spawn in the sea (catadromous) or in freshwaters (anadromous).

diagnosis (plural: diagnoses)**:** a list of characters and character states that helps distinguishing a taxon from other similar or related taxa.

dichromatism: two colours. Sexual dichromatism: difference in coloration or colour pattern between males and females.

dimorphism: occurrence of two distinct morphological types in a single population.

diploid (noun)**:** an organism that has a pair of each type of chromosomes, so that the basic (haploid) number of chromosomes is doubled.

disjunct: geographically widely separated.

dorso-hypural distance: distance measured from the dorsal-fin origin to the base of the median caudal ray. This measurement is often projected forward from the dorsal-fin origin, the point it defines (behind eye, at nostril, tip of snout, etc.) being useful in the diagnosis of some species (*see* Fig. 2).

dorsum: the upper surface of the body.

ecotone: the boundary between two habitats or ecosystems.

ecotype: populations of the same species that occur in distinct habitats, are distinguished from each other by morphological and/or physiological characterisitics and are genetically differentiated. The word 'ecotype' is now widely (and erroneously) used to refers to sympatric 'populations', more or less distinct, and "not yet a species". Because of this confusion, the word is not used here. *See also* p. 431.

embedded scales: scales partly or totally hidden in the skin.

embryo: developmental stage between the fertilization of the egg and the onset of external feeding. Called 'free embryo' between hatching and external feeding.

endemic: native and restricted to a given area.

epigean: surface dwelling (as opposed to hypogean or subterranean).

epilimnion: the upper level of a lake when the lake is stratified into distinct thermal layers.

epipelagic: the upper level of the water column, away from the shore.

epilithic: a plant or animal that lives on the surface of stones or rocks.

epithelium (noun), **epithelial** (adjective)**:** tissue composed of one or more layers of cells covering most internal and external surfaces of the body and organs.

established: an introduced species, which maintains itself in the wild by reproduction, without human intervention.

euryhaline: of a species that tolerates a wide range of salinity (opposite: stenohaline).

euryphagous: of a species feeding on a wide range of food (opposite: stenophagous).

eurytherm: of a species that tolerates a wide range of temperature (opposite: stenotherm).

eutrophic: pertaining to a body of water having a naturally high rate of biological production, or enriched by the anthropogenic introduction of nutrients, leading to absence of oxygen in deep waters in seasonally stratified lakes (*see also*: mesotrophic, oligotrophic).

exotic: not native, introduced to or invasive at a place in which it does not normally occur, and at which it forms a reproducing population.

extant: still living (as opposed to extinct).

extinct: a taxon that has died out. *See* p. 10.

extirpated: population(s) of an extant species that

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have now disappeared (not the same as extinction).

falcate: for fins: with a deeply concave (sickle-shaped) distal margin.

fimbriate: fringed with numerous small, elongate processes.

flank: in fish, the lateral part of the body.

form: *see* life-history form (p. 431).

fraenum (frenum)**:** a membranous fold of skin or membrane supporting or restricting the movement of a part or organ; for example, the band of tissue connecting the underside of the human tongue to the floor of the mouth. In Gobiidae, the transverse anterior membrane between the pelvic-fin rays (*see* Fig. 96)

genital papilla: a fleshy protuberance bearing the external genital opening; *see also:* urogenital papilla.

genome: a complete haploid set of chromosomes.

gill: respiratory organ located along the posterior edge of the gill arch, consisting of filamentous outgrowths, allowing gas exchange.

gill arches: bony or cartilaginous arches placed one behind the other on each side of the pharynx and supporting the gills.

gill filaments: each of the elongate subdivision of a gill.

gill rakers: forward projections (usually bony) along the anterior edge of the gill arch.

haploid (adjective)**:** having a single set of chromosomes; also, having the same number of sets of chromosomes as a germ cell or half as many as a somatic cell.

HL: head length.

homonyms: identical names given to two distinct taxa; the more recent (junior) homonym cannot be used and must be replaced.

hyaline: clear, glassy, translucent.

hybrid: offspring of cross between two species.

hybridogenous: of hybrid origin.

ichthyocide: a chemical used to kill fish.

ichthyofauna: the fish species of a given area.

imbricate: overlapping, like the shingles on a roof; refers to positioning and tile-like appearance of scales.

included: lower jaw included in upper jaw: lower jaw, the lateral edges of which are covered by overhanging upper jaw (*see* Fig. 47).

indigenous: native to a given area.

inferior: for the mouth: position in which the mouth is on the underside of the head; mouth opens downwards.

interstices: space between sand particles, pieces of gravel, rocks and other substrate materials.

introduced: of a species: non-native to a given locality or drainage, brought in with the intention of establishing a resident breeding populations.

introgression: the infiltration of the genes of one species into the gene pool of another by hybridisation and repeated backcrossing of the hybrid individuals with one or both parental species.

invasive: an [often exotic] species rapidly expanding its distribution, invading a range to which it is not native. Invasion usually follows an introduction event or the disappearance of a natural barrier to dispersal (for example, establishment of trans-basin linkages, damming, etc.).

isthmus: the narrow portion of the breast between the gill chambers and separating them (*see* Fig. 17).

juvenile: young and sexually immature but morphologically similar to the adults.

karyotype: the general appearance (size, number, shape) of the set of somatic chromosomes.

lachrymal (lacrimal)**:** first (anterior) infraorbital bone, under the skin on the side of the snout (below naris and anterior to cheek) (see Fig. 51).

lacustrine: pertaining to lakes; of a fish, living in lakes.

landlocked: a population of a normally diadromous species that is resident in a freshwater body, (often permanently) isolated from the sea, and where it completes the whole of its life cycle.

larva (plural: larvae)**:** a fish in the early phases of life, lasting from absorption of the yolk sack until as long as its morphology is unlike that of the juvenile.

lentic: of, or relating to, or living in still waters (e.g. lakes, ponds, marshes).

leptocephalus (plural: leptocephali)**:** an eel larva.

liman: lagoon at the estuary of a river created by a littoral bar blocking the access to the sea. A geomorphological feature typical of the northern coast of the Black Sea.

limnetic: of, or occurring in, the deeper, open waters of lakes or ponds.

lineage: the descendants of a common ancestor considered to be the founder of a taxon.

livebearer: a fish that bears live young rather than depositing eggs.

mandible: the lower jaw.

marbled: a generally uniform-coloured area with elongate marks of a different colour.

masl: meters above sea level.

maxilla (plural: maxillae)**:** the bones on each of the two halves of the upper jaw behind the premaxillae. These bones and the premaxillae form the two sides of the upper jaw.

maxillary: as an adjective, pertaining to or in the region of the upper jaw (for example, maxillary barbels), or more specifically to the max-

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illae; as a noun, the upper jaw.

mental barbels: chin barbels.

meristic: count of a series of discrete units of a morphological character, such as lateral line scales and fin-spines and rays.

mesotrophic: pertaining to a body of water with medium levels of nutrients, often clear water with beds of submerged aquatic plants (*see also*: oligotrophic, eutrophic).

metamorphosis: the period in which an organism undergoes a major change from one form or stage to another during its normal development. Examples: the transformation, in fishes, of a larva into a juvenile; in amphibians, of a tadpole into a frog.

migration: cyclical journey between different habitats at specific times of the year, usually for a specific purpose (breeding, feeding, etc.).

mode: the most frequently occurring value in a series of values (for example, lateral-line scale counts).

monophyletic: of a group of taxa that includes all descendants of a common ancestor.

montane: of, growing in, or inhabiting mountain areas.

morph: one of two or more alternative appearances exhibited by members of a species, genetically determined and retained during the entire life of a given individual, not related to sex or age. Light and black leopards are an example (*see also*: p. 431).

morphometrics: measurements of a measurable morphological character, such as length.

mtDNA: DNA from mitochondria.

mucous (adjective)**:** of, or secreting, or covered with, or resembling mucus.

mucus (noun)**:** a secretion of the mucosa, usually thick and slimy.

myomere: chevron-shaped bundles of muscle arranged in a series along the side of the body.

mysids: small shrimp-like crustaceans.

naked: lacking scales.

nape: the area of the dorsum immediately behind the occipital region of the head.

naris (plural: nares)**:** the openings of the nostril. The nostril of most fishes has an anterior and a posterior naris.

neuromast: exposed or semi-exposed receptor of the sensory nervous system sensitive to mechanical stimuli (for example, water movements), usually contained in canals of the lateral line system on the body and head (the seismo-sensory system in the Russian literature), or exposed (as in many Gobiidae).

nomenclatorial: relating to nomenclators such as lists, indexes, etc.

nomenclatural: relating to nomenclature.

nomenclature: the system of names given to organisms, and the provisions for their formation and use. The names of animals are governed by the International Code of Zoological Nomenclature, fourth edition (1999), adopted by the International Union of Biological Sciences. The International Commission on Zoological Nomenclature (comprised of zoologists) is responsible for amendments to the Code, to clear special or conflicting cases, and has plenary powers to suspend the application of the Code in specific cases. When necessary, the Commission issues mandatory rulings on names of animals.

nuchal: pertaining to the nape.

nuptial: of, relating to, or occurring during the mating season.

oligotrophic: pertaining to a seasonally stratified body of water having a low rate of biological production, with oxygen in deep waters (*see also*: mesotrophic, eutrophic).

oviparous: producing eggs that hatch outside of the body.

opercle: the group of bones and associated membranes (usually movable) which cover the gills (*see* Fig. 44).

operculum: one of the bones of the opercle (*see* Fig. 44).

parasitism: the relation between two species in which the parasite obligatorily depends on the metabolism of the host. The host does not die because of the presence of the parasite, at least not immediately.

paired fins: the pectoral and pelvic fins.

Palaearctic (Palearctic)**:** the biogeographic realm including Europe, Asia north of the Himalayas, and northern Africa (excluding the drainage of the Nile).

palatine: pertaining to the roof of the mouth.

papilla: a small fleshy protuberance.

parapatric: two or more species sharing some sort of evolutionary relationships and whose ranges are separate but in contact or with only slight marginal overlap. *See also:* allopatric, sympatric.

pelagic: of, relating to, or living in open oceans or lakes (rather than waters adjacent to land).

periphyton: small, plant-like organisms, living on a substrate. *See also:* aufwuchs, epilithic.

phenotype: the observable physical or biochemical characteristics of an organism. Also: an individual or group of organisms exhibiting a particular set of physical or biochemical characters.

phototaxis (adjective: phototactic)**:** the movement of an entire organism in response to light. Positive phototaxis is movement towards the light,

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negative phototaxis is movement to escape the light.

phylogeography: the genetic study of the processes controlling the geographic distributions of lineages by constructing the genealogies of populations and genes.

piedmont: an area of land formed or lying at the foot of a mountain range.

pocket: scale pocket: the envelope of skin in which the anterior portion of a scale is embedded.

polje: a wide closed depression in karstic areas, without surface outflow (but often underground outflow).

polymorphism: different appearances [morphs] exhibited by members of a species, genetically determined and retained during the entire life of a given individual. *See* p. 431).

pool: deep water between shallow areas of a stream, where the current is still or relatively slow, and the surface relatively calm.

portion: used here as a fraction of eggs from a gonad spawned during one spawing act or within a short time of spawing, usually 1-2 days, followed by a period during which the individual does not spawn.

postorbital length: distance from posterior margin of eye to posterior-most point of opercle to the posterior-most point of the opercle or opercular membrane.

predation: the relation between two animals in which one eats all or part of the other.

premaxilla (plural: premaxillae)**:** the anterior-most bone of each upper jaw.

preoperculum: one of the bones of the opercle (*see* Fig. 44).

protrusible: capable of being thrust forward (synonym: protractile).

range: the geographical area occupied by a taxon.

rays: soft rays: in a fin, the paired (a right and a left parts) structures, usually segmented (jointed) and branched, which support the membranes (*see* Fig. 7b).

rheophilic: associated with moderate to swift current in streams.

riffles: a stream habitat characterised by relatively shallow water (usually less than 0.5 m), moderate to swift current (0.5–2.0 m/s), stone to large-gravel substrate and with a turbulent surface.

rudimentary rays: (also procurrent rays) small unbranched rays in front of upper and lower unbranched principal caudal-fin ray, often hidden in skin; not included in ray counts.

run: stream of flowing water, faster than a pool and slower than a riffle, with a smooth surface.

saddle: a saddle-shaped colour mark along the dorsum.

scaled: covered with scales.

semi-anadromous: those species, populations or individuals that migrate between fresh and brackish water to spawn in freshwaters.

serra (plural: serrae)**:** small, pointed, tooth-like structures, organised in a row, like the teeth of a saw.

serration: a series or set of teeth or notches.

SL: *see* standard length.

sneaker: precocial, sexually mature male that tries to fertilise the eggs of a spawning pair.

sp.: added behind a genus name and followed by a geographic name or a descriptive feature indicates a species whose formal scientific description has not yet been published and still without formal scientific name (e.g. *Rutilus* sp. Sperchios).

sp. (plural: spp.)**:** added behind a genus name but not followed by a geographic or other denomination indicates a species identified to the genus level but that was not or could not be identified to species level (e.g. *Coregonus* sp.); may also mean any member of that genus (for example, *Cobitis* spp. may mean 'all species of *Cobitis*'). *See also:* aff, cf.

speciation: the evolutionary process by which new species arise.

Allopatric speciation: a population splits into two or more allopatric (geographically isolated) populations (by emigration, habitat fragmentation, etc.), which then diverge.

Parapatric speciation: similar to allopatric speciation, but the two species evolve from contiguous populations.

Peripatric speciation (peripheral isolation): similar to allopatric speciation, but one (or more) of the population(s) is (are) much smaller than the other and usually at the edge of the range.

Sympatric speciation: species diverge while remaining sympatric (sharing the same geographical range and often the same habitat).

species flock: an accumulation of a relatively large number of closely related species confined to a narrowly circumscribed area (*see* p. 402).

specimen: an individual fish (or part thereof), usually preserved for study, identification or museum deposition.

spent: refers to adults that have recently completed spawning.

spine: in a fin, a median (unpaired) structure, never branched, never segmented, generally hard and pointed, which usually supports the membrane (*see* Fig. 7a).

spinous: (of a fin ray) resembling a spine, shaped

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like a spine.

sporadic species: a species that seems to be indifferent to the water salinity (euryhaline) and usually occurs in estuaries; examples include many species of Clupeidae, Mugilidae and Gobiidae.

spot: a roundish pigmented mark, about the size of the eye.

squamation: the state, the aspect, and/or the arrangement of the scales.

standard length: the length of a fish, measured from the anterior-most point of the snout or upper lip to the base of the median caudal rays.

stellate: star-shaped; having radiating extensions.

stenohaline: of a species that has very narrow, specific salinity requirements or tolerance (opposite: euryhaline).

stenophagous: of a species feeding on a very narrow, specialised type of food (opposite: euryphagous, omnivorous).

stenotherm: of a species with very narrow temperature tolerance or preference (opposite: eurytherm).

stock: an informal assemblage of individuals or a population, differing from others such assemblages by morphological, developmental, ecological or other characteristics, usually within a given range, and of unknown taxonomic status (i.e. it has not yet been investigated whether it is a local population, a form, an ecotype or a distinct species).

stripe: a longitudinal colour mark.

stunt: an animal whose growth or development has been curtailed. In fishes, stunting usually results from food shortage or unfavourable habitat. Stunted fishes often retain a juvenile appearance.

subadult: a juvenile of approximately the size of small adults; adult but not sexually mature; often used when stage of sexual maturity is uncertain.

subalpine: between the low country and the central, high altitude part of the Alps, on the northern and southern sides.

substrate (substratum)**:** the bottom material; also, the bottom over which the fish lives.

subterminal: for the mouth: position in which the anterior end of the closed mouth is just below the tip of the snout; mouth usually opens downwards.

superior: for the mouth: position in which the anterior end of the closed mouth is distinctly above the tip of the snout; mouth usually opens upwards.

sympatric: two or more species whose ranges overlap.

symphysis: the point of coalescence of two bones.

syntopic: two or more species, which occur together in the same habitat.

synonyms: two or more names applied to a single taxon, for example when individuals formerly described as constituting two species are now united in a single species. In such cases, the first created name is the valid name of the taxon.

systematics (plural, but used with a singular verb [adjective: systematic])**:** the study of an organism's diversity and the pattern of evolutionary relationships existing within this diversity.

taxon (plural: taxa)**:** one or a group of organisms that is given a proper name, or a group that could be given a name but remains unnamed as a matter of convention (species, genus, family, lineage, etc.).

taxonomy: the theory and practice of describing the diversity of organisms and ordering this diversity into a system reflecting evolutionary relationships.

terminal: for the mouth: position in which the anterior end of the closed mouth is level with the tip of the snout; mouth usually opens forwards.

tessellated: a colour pattern of the fins created by small, darkly pigmented areas alternating with small lightly pigmented or unpigmented areas.

tetraploid (noun)**:** an organism that has four times the haploid number of chromosomes.

trait: a genetically determined feature that is not fixed in a population, so different individuals may show different traits of a given character. Different traits of the same characters may be present in different combinations in different species or populations.

tricuspid: with three cusps (points, for example, of a tooth; *see* Fig. 87c).

triploid (noun)**:** an organism that has three times the haploid number of chromosomes.

translocation: to remove or transfer part of a population from one place to another within the distribution area.

tubercles: small keratinized (horny) protuberances on the head, body or fins, often more developed in males, or present only during a given period of life. Tubercles are used for sexual stimulation, as contact organs while spawning, and in territorial aggression (breeding or nuptial tubercles) (*see* Wiley & Collette, 1970). In some species, tubercles are present in both sexes, throughout their life, and help to maintain position and orientation in strong current, or have a hydrodynamic function.

turbid: water clouded by suspended inorganic particles, usually clay and silt.

ubiquitous: of a species that is widely distributed and present in various habitats in a given area.

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urogenital papilla: fleshy protuberance bearing a common opening of urinary and reproductive tracts.

unicuspid: with a single cusp (point, for example, of a tooth; *see* Fig. 87a).

unpaired fins: the dorsal, anal and caudal fins.

valid name: In taxonomic context, a valid name (as defined by the International Code of Zoological Nomenclature) is the correct name that must be applied to a species.

valid species: a species that exists in reality and is recognized (diagnosable) as opposed to a species that had been hypothesised to be distinct but does not exist, is no longer recognized, is treated as a synonym, etc.

vicarious species: the non-diadromous, strictly freshwater *species* of fish families otherwise including true marine species; examples are the freshwater shad *Alosa agone*, the blenny *Salaria fluviatilis* and many Gobiidae.

villiform teeth: numerous small, sharp, pointed teeth.

vs.: [Latin] versus.

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The authors

Maurice Kottelat is an independent taxonomist, based in Switzerland. He is a renowned fish taxonomist and has conducted fish surveys in Europe and South, East and Southeast Asia for 28 years, and discovered and described more than 350 species new to science. He is Dr. Sc. of the University of Amsterdam; Dr. Honoris Causa of the University of Neuchâtel; Honorary Research Associate of the Raffles Museum of Biodiversity Research, National University of Singapore; editor of the scientific journal *Ichthyological Exploration of Freshwaters*; present president of the *European Ichthyological Society*; and member of the *International Commission on Zoological Nomenclature*. He is author of 8 books and some 260 scientific publications on fish taxonomy, nomenclature and ecology.

Jörg Freyhof is a research scientist at the Leibniz Institute of Freshwater Ecology and Inland Fisheries in Berlin. He is an authority on the ecology and taxonomy of European freshwater fishes with a focus on conservation and evolutionary ecology, with 20 years of field experience throughout Europe, as well as in Turkey, Iran, Vietnam, Russia and West Africa. He is Dr. Sc. of the University of Bonn; lecturer at the Biology Faculty of the Humboldt University in Berlin; and the European Regional Vice-Chair of the *IUCN-SSC/WI Freshwater Fish Specialist Group*. He authored some 100 scientific publications on fish ecology, biogeography and taxonomy.

ISBN 978-2-8399-0298-4